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Background Information for Proposed Standards

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Standards of Performance for the control of emissions from publication rotogravure printing presses are being proposed under the authority of Section 111 of the Clean Air Act. These standards would apply only to presses printing saleable products and for which construction or modification began on or after the date of proposal of the regulation. This document contains background information and environmental and economic impact assessments of the regulatory alternatives considered in developing proposed standards.

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Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

October 1980

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ENVIRONMENTAL PROTECTION AGENCY

Background Information
and Draft Environmental Impact Statement
for Publication Rotogravure Printing

Prepared by:

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1. The proposed standards of performance would limit emissions of volatile organic compounds (VOC) from new, modified, and reconstructed publication rotogravure printing presses. Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended, directs the Administrator to establish standards of performance for any category of new stationary source of air pollution that ". . . causes or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare." The Midwest and East Coast Regions of the United States are particularly affected.

2. Copies of this document have been sent to the following Federal Departments: Labor, Health and Human Services, Defense, Transportation, Agriculture, Commerce, Interior, and Energy; the National Science Foundation; the Council on Environmental Quality; members of the State and Territorial Air Pollution Program Administrators; the Association of Local Air Pollution Control Officials; EPA Regional Administrators; and other interested parties.

3. The comment period for review of this document is 60 days. Mr. Gene W. Smith, Section Chief, may be contacted regarding the date of the comment period.

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METRIC CONVERSION TABLE

In keeping with U.S. Environmental Protection Agency policy, metric units are used in this report. These units may be converted to common English units by using the following conversion factors:

Metric Unit	Metric Name	Equivalent English Unit
	LENGTH	
m	meter	39.3700 in.
m	meter	3.2810 ft.
	VOLUME	
l	liters	0.2642 U.S. gal.
m^3	cubic meters	264.2 U.S. gal.
Mm^3	mega-cubic meters (10^6 m^3)	3.53 X 10^7 ft.^{3}
	WEIGHT	
Kg	kilogram (10^3 grams)	2.2046 lb.
Mg	megagram (10^6 grams)	1.1023 tons
Gg	gigagram (10^9 grams)	1,102.3 tons
	ENERGY	
GJ	gigajoule	9.48 X 10^5 Btu
GJ	gigajoule	277.76 KWh
J/g	joule per gram	0.430 Btu/lb
	VOLUMETRIC FLOW	
m^3/hr	cubic meters per hour	0.5886 ACFM (ft^3/min)
Nm^3/hr	normal cubic meters per hour	0.5886 SCFM (ft^3/min)
	SPEED	
m/s	meters per second	196.86 ft/min
	SOLVENT VAPOR CONCENTRATION	
g/m^3	grams per cubic meter air	266 ppmv

Temperature in degrees Celcius (^oC) can be converted to temperature in degrees Farenheit (^oF) by the following formula:

$$(^oF) = 1.8\ (^oC) + 32$$

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1. SUMMARY

1.1 REGULATORY ALTERNATIVES

This Background Information Document (BID) supports proposal of the Federal Regulation for limiting volatile organic compounds (VOC) vapor emissions from the publication rotogravure printing industry. New Source Performance Standards (NSPS) or standards of performance for new, modified, and reconstructed publication rotogravure printing presses are being proposed under Section 111 of the Clean Air Act. The source of the VOC emissions are the solvent components in the inks, extenders, and varnishes used at the printing presses, as well as solvent added for printing and cleaning.

The three regulatory alternatives considered are presented in Chapter 6. These alternatives call for an overall reduction of VOC emissions at 75, 80, and 85 percent levels. The 75 percent control level represents capturing the dryer exhausts from older presses. This baseline level corresponds to the control techniques guideline (CTG) recommendation for existing facilities, which the states are expected to use in developing their State Implementation Plans (SIP). The 80 percent control level represents capturing the dryer exhausts from new presses. This corresponds to a typical, well-controlled facility. The 85 percent control level represents capturing the dryer exhausts from new presses, as well as some of the fugitive VOC vapors. This corresponds to the best-demonstrated controlled facility in this industry. Test data, presented in Appendix C, shows that the typical plants in this industry could also potentially achieve the highest level of control by directing their existing fugitive capture vents to a control device, rather than to the atmosphere.

All three regulatory control levels can be achieved with the installation of add-on control equipment. Fixed-bed carbon adsorption with solvent recovery is the most popular method currently used to control VOC emissions from this industry. In addition, overall emission reductions greater than about 80 percent require some type of fugitive vapor capture system to be installed around the presses. This industry is researching the possibilities of using waterborne ink systems so that add-on controls would not be required to meet the proposed VOC emission standards. However, only solvent-borne ink systems are presently used for publication rotogravure printing.

1.2 ENVIRONMENTAL IMPACT

Detailed discussions of the environmental and energy impacts associated with the three alternatives are presented in Chapter 7. A summary of the relative impacts is presented in Table 1-1. The estimated effects shown in this chart are based on comparisons between the impacts of the higher NSPS control alternatives and the baseline control level. 75 percent overall control is the comparison baseline and, therefore, its relative impact values are zero. The relative impacts from a delay in promulgation of Federal NSPS are also shown to be zero. This effect is based on the assumption that all new facilities, even without Federal standards, would probably install solvent recovery systems with overall control at about the 75 percent level. Recovery of about 75 percent of the solvent used is shown in Chapter 6 to be the minimum recycle amount required for dilution of the printing inks. Solvent recovery can help alleviate the problems of limited solvent supplies and increasing solvent costs. The actual effect of delayed standards depends on how long the delay is and what control level is required by the individual states. However, the 75 percent overall control level is expected to be the minimum level adopted for all the SIP.

The potential VOC vapor emissions from presses used in this industry, for the year 1985, are projected to be about 236,000 Mg (260,000 tons). If all facilities were controlled at the 75 percent baseline level, the resulting emissions would be about 59,000 Mg (65,000 tons) per year. The baseline emissions would be reduced by about an additional 7 percent, if all new facilities were controlled at the 80 percent level, with existing facilities controlled at the 75 percent level. Similarly, the emissions would be reduced by about an additional 13 percent over baseline control level, if all new facilities were controlled at the 85 percent level.

TABLE 1-1. ASSESSMENT OF ENVIRONMENTAL AND ECONOMIC **RELATIVE IMPACTS** FOR EACH REGULATORY ALTERNATIVE CONSIDERED

ADMINISTRATIVE ACTION	AIR IMPACT	WATER IMPACT	SOLID WASTE IMPACT	ENERGY IMPACT	NOISE IMPACT	ECONOMIC IMPACT
85% overall control	+4**	-2**	-2**	+3**	0	-2** -3*
80% overall control	+3**	-1**	-1**	+2**	0	+3** +2*
75% overall control (Baseline)	0	0	0	0	0	0
Delayed Standards (SIP control)	0	0	0	0	0	0

Key:
+ Beneficial impact
- Adverse impact
0 No impact
1 Negligible impact

2 Small impact
3 Moderate impact
4 Large impact

* Short-term impact
** Long-term impact
*** Irreversible impact

Emissions of air pollutants from secondary sources result from the operation of carbon adsorption control systems. Required electrical power is generated in various types and sizes of separate offsite facilities, which are already governed by regulations. An accurate assessment of this pollution source was not attempted. Total emissions from fuel combustion to generate the required steam was estimated to represent less than 0.5 percent of the corresponding VOC emission reductions from the publication rotogravure presses. Hydrocarbon vapors makeup less than one percent of the total fuel combustion emissions. Therefore, the resulting total air pollutants emitted from secondary sources only slightly offset the primary impact of reducing VOC emissions.

Dissolved solvent in the condensate from solvent recovery systems represents a potential water pollution source. The amount of condensate discharged increases in a direct proportion with the amount of solvent recovered. However, the total amount of solvent discharged with the condensate represents less than 0.1 percent of the VOC solvent recovered from the presses. Also, this potential water pollution source can be virtually eliminated by demonstrated removal of the dissolved solvent content and recycling the resultant solvent-free condensate as boiler feed water.

The spent carbon, carbon fines, and used fiberglass air filters are the only sources of solid waste pollution. The spent carbon can be treated and reused, or disposed of using readily available methods. There should be no problem in disposing the carbon fines or used fiberglass filters.

The operation of carbon adsorption control systems require electrical energy for running the solvent laden air (SLA) fans, and fuel energy for steam generation. The industry's total direct energy consumption, in the year 1985, for VOC emission controls at the 75 percent level would be about 2.6 million GJ (2.5 X 10^{12} Btu). The direct energy consumption would be increased by about an additional 3 to 9 percent for controlling new press emissions at the 80 and 85 percent levels, respectively.

However, the energy impact analysis presented in section 7.4 shows that there would be a national net energy savings, when the fuel energy value of the recovered solvent is considered. National energy consumption, in the year 1985, would be actually decreased by about 5.6 million GJ (5.3 X 10^{12} Btu), with VOC emission controls and solvent recovery at the 75 percent level, in this industry. The nationwide energy savings would be further increased by about an additional 2 to 3 percent for controlling new press emissions at the 80 and 85 percent levels, respectively.

The only significant source of noise would be from the large SLA fans. However, these are normally installed in an enclosed housing, and should not affect the surrounding environment.

1.3 REGULATORY ANALYSIS

Executive Order 12044 requires that the EPA prepare a regulatory analysis of the economic effects of new significant regulations. A detailed discussion of the economic impacts of controlling VOC emissions at all three regulatory levels is presented in Chapter 8. A summary of the relative economic impacts is also presented in Table 1-1.

The capital costs of VOC emission controls, through the year 1985, for all new presses controlled at the 75 percent level would be about $46.2 million. Control at the 80 percent and 90 percent levels would further increase the capital costs by about 6 percent and 36 percent, respectively. These emission control capital investments represent from 5 to 9 percent of the total costs for the new printing plants, plus emission control systems. However, the annual operating costs are more than offset by the cost value of the recovered solvent, resulting in annual savings at all three control levels.

The maximum return on investment (ROI) for solvent recovery systems would occur for overall control at slightly over the 80 percent level. At the 80 percent level, the positive ROI would yield a small short-term increase in cost savings relative to baseline control. In addition, these economic benefits would increase in the long-term after the capital costs of the control system are paid off. At the 85 percent level, the positive ROI is lower than with control at the baseline level. Consequently, 85 percent control would yield a moderate short-term adverse impact relative to baseline control. However, this adverse impact would decrease somewhat in the long-term once the capital investments are paid off.

These cost savings make the installation of emission control/solvent recovery systems profitable at all three control levels. This economic incentive is expected to increase in the future, as the price of solvent increases. The resulting return on emission controls investment is not quite as high as for investments in new printing equipment. However, this industry, unlike other industries, can still get some return on their emission controls investments. In addition, the profitability analysis presented in section 8.4 shows that this industry's profit margin would not decrease by more than 0.2 percentage point, even at the 85 percent control level. Therefore, these minimal changes in profitability should not cause any significant price increases for publication gravure products.

2. INTRODUCTION

2.1 BACKGROUND AND AUTHORITY FOR STANDARDS

Before standards of performance are proposed as a Federal regulation, air pollution control methods available to the affected industry and the associated costs of installing and maintaining the control equipment are examined in detail. Various levels of control based on different technologies and degrees of efficiency are expressed as regulatory alternatives. Each of these alternatives is studied by EPA as a prospective basis for a standard. The alternatives are investigated in terms of their impacts on the economics and well-being of the industry, the impacts on the national economy, and the impacts on the environment. This document summarizes the information obtained through these studies so that interested persons will be able to see the information considered by EPA in the development of the proposed standard.

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 U.S.C. 7411) as amended, hereinafter referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution which ". . . causes, or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."

The Act requires that standards of performance for stationary sources reflect ". . . the degree of emission reduction achievable which (taking into consideration the cost of achieving such emission reduction, and any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated for that category of sources." The standards apply only to stationary sources, the construction or modification of which commences after regulations are proposed by publication in the Federal Register.

The 1977 amendments to the Act altered or added numerous provisions that apply to the process of establishing standards of performance.

1. EPA is required to list the categories of major stationary sources that have not already been listed and regulated under standards of performance. Regulations must be promulgated for these new categories on the following schedule:

   a. 25 percent of the listed categories by August 7, 1980.
   b. 75 percent of the listed categories by August 7, 1981.
   c. 100 percent of the listed categories by August 7, 1982.

A governor of a State may apply to the Administrator to add a category not on the list or may apply to the Administrator to have a standard of performance revised.

2. EPA is required to review the standards of performance every 4 years and, if appropriate, revise them.

3. EPA is authorized to promulgate a standard based on design, equipment, work practice, or operational procedures when a standard based on emission levels is not feasible.

4. The term "standards of performance" is redefined, and a new term "technological system of continuous emission reduction" is defined. The new definitions clarify that the control system must be continuous and may include a low- or non-polluting process or operation.

5. The time between the proposal and promulgation of a standard under Section 111 of the Act may be extended to 6 months.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, taking into consideration the cost of achieving such emission reduction, any non-air-quality health and environmental impacts, and energy requirements.

Congress had several reasons for including these requirements. First, standards with a degree of uniformity are needed to avoid situations where some states may attract industries by relaxing standards relative to other states. Second, stringent standards enhance the potential for long-term growth. Third, stringent standards may help achieve long-term cost savings by avoiding the need for more expensive retrofitting when pollution ceilings may be reduced in the future. Fourth, certain types of standards for coal-burning sources can adversely affect the coal market by driving up the price of low-sulfur coal or effectively excluding certain coals from the reserve base because their untreated pollution potentials are high. Congress does not intend that new source performance standards contribute to these problems. Fifth, the standard-setting process should create incentives for improved technology.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. States are free under Section 116 of the Act to establish even more stringent emission limits than those established under Section 111 or those necessary to attain or maintain the National Ambient Air Quality Standards (NAAQS) under Section 110. Thus, new sources may in some cases be subject to limitations more stringent than standards of performance under Section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area that falls under the prevention of significant deterioration of air quality provisions of Part C of the Act. These provisions require, among other things, that major emitting facilities to be constructed in such areas are to be subject to best available control technology. The term Best Available Control Technology (BACT), as defined in the Act, means

> ". . . an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from, or which results from, any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques

> for control of each such pollutant. In no event shall application of "best available control technology" result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard established pursuant to Sections 111 or 112 of this Act. (Section 169(3))."

Although standards of performance are normally structured in terms of numerical emission limits where feasible, alternative approaches are sometimes necessary. In some cases physical measurement of emissions from a new source may be impractical or exorbitantly expensive. Section 111(h) provides that the Administrator may promulgate a design or equipment standard in those cases where it is not feasible to prescribe or enforce a standard of performance. For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling. The nature of the emissions, high concentrations for short periods during filling and low concentrations for longer periods during storage, and the configuration of storage tanks make direct emission measurement impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

In addition, Section 111(j) authorizes the Administrator to grant waivers of compliance to permit a source to use innovative continuous emission control technology. In order to grant the waiver, the Administrator must find: (1) a substantial likelihood that the technology will produce greater emission reductions than the standards require or an equivalent reduction at lower economic energy or environmental cost; (2) the proposed system has not been adequately demonstrated; (3) the technology will not cause or contribute to an unreasonable risk to the public health, welfare, or safety; (4) the governor of the State where the source is located consents; and (5) the waiver will not prevent the attainment or maintenance of any ambient standard. A waiver may have conditions attached to assure the source will not prevent attainment of any NAAQS. Any such condition will have the force of a performance standard. Finally, waivers have definite end dates and may be terminated earlier if the conditions are not met or if the system fails to perform as expected. In such a case, the source may be given up to three years to to meet the standards with a mandatory progress schedule.

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Adminstrator to list categories of stationary sources. The Administrator ". . . shall include a category of sources in such list if in his judgement it causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare." Proposal and promulgation of standards of performance are to follow.

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of a system for assigning priorities to various source categories. The approach specifies areas of interest by considering the broad strategy of the Agency for implementing the Clean Air Act. Often, these "areas" are actually pollutants emitted by stationary sources. Source categories that emit these pollutants are evaluated and ranked by a process involving such factors as: (1) the level of emission control (if any) already required by State regulations, (2) estimated levels of control that might be required from standards of performance for the source category, (3) projections of growth and replacement of existing facilities for the source category, and (4) the estimated incremental amount of air pollution that could be prevented in a preselected future year by standards of performance for the source category. Sources for which new source performance standards were promulgated or under development during 1977, or earlier, were selected on these criteria.

The Act amendments of August 1977 establish specific criteria to be used in determining priorities for all major source categories not yet listed by EPA. These are: (1) the quantity of air pollutant emissions that each such category will emit, or will be designed to emit; (2) the extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare; and (3) the mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source standards of performance.

The Administrator is to promulgate standards for these categories according to the schedule referred to earlier.

In some cases it may not be feasible immediately to develop a standard for a source category with a high priority. This might happen when a program of research is needed to develop control techniques or because techniques for sampling and measuring emissions may require refinement. In the developing of standards, differences in the time required to complete the necessary investigation for different source categories must also be considered. For example, substantially more time may be necessary if numerous pollutants must be investigated from a single source category. Further, even late in the development process the schedule for completion of a standard may change. For example, inablility to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling. Nevertheless, priority ranking is, and will continue to be, used to establish the order in which projects are initiated and resources assigned.

After the source category has been chosen, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution, and emissions from some of these facilities may vary from insignificant to very expensive to control. Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there is no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by a standard of performance, not all pollutants or facilities within that source category may be covered by the standards.

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost, the non-air-quality health and environmental impacts, and the energy requirements of such control; (3) be applicable to existing sources that are modified or reconstructed as well as new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

The objective of a program for developing standards is to identify the best technological system of continuous emission reduction that has been adequately demonstrated. The standard-setting process involves three principal phases of activity: (1) information gathering, (2) analysis of the information, and (3) development of the standard of performance.

During the information-gathering phase, industries are queried through a telephone survey, letters of inquiry, and plant visits by EPA representatives. Information is also gathered from many other sources, and a literature search is conducted. From the knowledge acquired about the industry, EPA selects certain plants at which emission tests are conducted to provide reliable data that characterize the pollutant emissions from well-controlled existing facilities.

In the second phase of a project, the information about the industry and the pollutants emitted is used in analytical studies. Hypothetical "model plants" are defined to provide a common basis for analysis. The model plant definitions, national pollutant emission data, and existing State regulations governing emissions from the source category are then used in establishing "regulatory alternatives." These regulatory alternatives are essentially different levels of emission control.

EPA conducts studies to determine the impact of each regulatory alternative on the economics of the industry and on the national economy, on the environment, and on energy consumption. From several possibly applicable alternatives, EPA selects the single most plausible regulatory alternative as the basis for a standard of performance for the source category under study.

In the third phase of a project, the selected regulatory alternative is translated into a standard of performance, which, in turn, is written in the form of a Federal regulation. The Federal regulation, when applied to newly constructed plants, will limit emissions to the levels indicated in the selected regulatory alternative.

As early as is practical in each standard-setting project, EPA representatives discuss the possibilities of a standard and the form it might take with members of the National Air Pollution Control Techniques Advisory Committee. Industry representatives and other interested parties also participate in these meetings.

The information acquired in the project is summarized in the Background Information Document (BID). The BID, the standard, and a preamble explaining the standard are widely circulated to the industry being considered for control, environmental groups, other government agencies, and offices within EPA. Through this extensive review process, the points of view of expert reviewers are taken into consideration as changes are made to the documentation.

A "proposal package" is assembled and sent through the offices of EPA Assistant Administrators for concurrence before the proposed standard is officially endorsed by the EPA Administrator. After being approved by the EPA Administrator, the preamble and the proposed regulation are published in the Federal Register.

As a part of the Federal Register announcement of the proposed regulation, the public is invited to participate in the standard-setting process. EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standard with interested parties. All public comments are summarized and incorporated into a second volume of the BID. All information reviewed and generated in studies in support of the standard of performance is available to the public in a "docket" on file in Washington, D. C.

Comments from the public are evaluated, and the standard of performance may be altered in response to the comments.

The significant comments and EPA's position on the issues raised are included in the "preamble" of a "promulgation package," which also contains the draft of the final regulation. The regulation is then subjected to another round of review and refinement until it is approved by the EPA Administrator. After the Administrator signs the regulation, it is published as a "final rule" in the Federal Register.

2.4 CONSIDERATION OF COSTS

Section 317 of the Act requires an economic impact assessment with respect to any standard of performance established under Section 111 of the Act. The assessment is required to contain an analysis of (1) the costs of compliance with the regulation, including the extent to which the cost of compliance varies depending on the effective date of the regulation and the development of less expensive or more efficient methods of compliance, (2) the potential inflationary or recessionary effects of the regulation, (3) the effects the regulation might have on small business with respect to competition, (4) the effects of the regulation on consumer costs, and (5) the effects of the regulation on energy use. Section 317 also requires that the economic impact assessment be as extensive as practicable.

The economic impact of a proposed standard upon an industry is usually addressed both in absolute terms and in terms of the control costs that would be incurred as a result of compliance with typical, existing State control regulations. An incremental approach is necessary because both new and existing plants would be required to comply with State regulations in the absence of a Federal standard of performance. This approach requires a detailed analysis of the economic impact from the cost differential that would exist between a proposed standard of performance and the typical State standard.

Air pollutant emissions may cause water pollution problems, and captured potential air pollutants may pose a solid waste disposal problem. The total environmental impact of an emission source must, therefore, be analyzed and the costs determined whenever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made for proposed standards. It is also essential to know the capital requirements for pollution control systems already placed on plants so that the additional capital requirements necessitated by these Federal standards can be placed in proper perspective. Finally, it is necessary to assess the availability of capital to provide the additional control equipment needed to meet the standards of performance.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 requires Federal agencies to prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decision-making process of Federal agencies a careful consideration of all environmental aspects of proposed actions.

In a number of legal challenges to standards of performance for various industries, the United States Court of Appeals for the District of Columbia Circuit has held that environmental impact statements need not be prepared by the Agency for proposed actions under Section 111 of the Clean Air Act. Essentially, the Court of Appeals has determined that the best system of emission reduction requires the Administrator to take into account counter-productive environmental effects of a proposed standard, as well as economic costs to the industry. On this basis, therefore, the Court established a narrow exemption from NEPA for EPA determination under Section 111.

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969." (15 U.S.C. 793(c)(1))

Nevertheless, the Agency has concluded that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, although not legally required to do so by section 102(2)(C) of NEPA, EPA has adopted a policy requiring that environmental impact statements be prepared for various regulatory actions, including standards of performance developed under section 111 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, a separate section in this document is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are discussed.

2.6 IMPACT ON EXISTING SOURCES

Section 111 of the Act defines a new source as ". . . any stationary source, the construction or modification of which is commenced . . ." after the proposed standards are published. An existing source is redefined as a new source if "modified" or "reconstructed" as defined in amendments to the general provisions of Subpart A of 40 CFR Part 60, which were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Promulgation of a standard of performance requires States to establish standards of performance for existing sources in the same industry under Section 111 (d) of the Act if the standard for new sources limits emissions of a designated pollutant (i.e., a pollutant for which air quality criteria have not been issued under Section 108 or which has not been listed as a hazardous pollutant under Section 112). If a State does not act, EPA must establish such standards. General provisions outlining procedures for control of existing sources under Section 111(d) were promulgated on November 17, 1975, as Subpart B of 40 CFR Part 60 (40 FR 53340).

2.7 REVISION OF STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, Section 111 of the Act provides that the Administrator ". . . shall, at least every four years, review and, if appropriate, revise . . ." the standards. Revisions are made to assure that the standards continue to reflect the best systems that become available in the future. Such revisions will not be retroactive, but will apply to stationary sources constructed or modified after the proposal of the revised standards.

3. THE PUBLICATION ROTOGRAVURE PRINTING INDUSTRY PROCESSES AND POLLUTANT EMISSIONS

3.1 GENERAL

The publication rotogravure printing industry is a highly specialized segment of the graphic arts industry. The graphic arts industry, which includes all printing, publishing, and allied industries, is characterized under "Standard Industrial Classification" (SIC) 27 by the U.S. Department of Commerce.[1] Commercial printing is subclassified under SIC 275; additional subclassification separates gravure printing under SIC 2754. Gravure printed products are further divided into four SIC subcategories. The two industry sectors of packaging and specialties gravure are represented under SIC 27542 and 27544, respectively. Publication and advertising gravure products are listed under separate SIC Numbers 27541 and 27543, respectively. The gravure industry, however, groups these two product areas into a common third sector. The dollar value of advertising is really too small realative to the other sectors to be listed separately. In addition, advertising products are handled by the same gravure presses as publication products.

Gravure facilities printing products in the combined third sector are the subject of this study. Publication rotogravure printing involves the high-volume printing of high-quality, smooth paper items such as magazines. Also high volume, but somewhat lower quality items such as newspaper and advertising supplements, and all types of catalogs are printed on the same rotogravure presses. Most of these items are in full color. The combination of these gravure products accounted for over $2 billion in sales in 1976.[2] During that year weekly averages of 73.5 million regularly scheduled rotogravure newspaper supplements and 109.6 million preprinted inserts were distributed. In addition, a monthly average of 187 million magazines were printed wholly or in part by rotogravure. Facilities printing the packaging and specialty gravure products are not considered in this study. A more detailed economic profile of the industry is presented in Chapter 8.

A list of the publication rotogravure printing establishments operating as of January 1978 is presented in Table 3-1. This list shows 27 printing establishments throughout 15 states. A large portion of these are located in the midwest and northeast sections of the United States. One of these establishments ceased operation in mid-1978. One new establishment is expected to begin operation during 1979.

Gravure printing is the fastest growing segment within the entire printing industry. Furthermore, publication rotogravure printing is the fastest growing sector of the gravure market. A reliable estimate of the anticipated growth rate of the publication rotogravure industry was not available. However, growth projections were available for total gravure printing and the entire printing industry. U.S. Department of Commerce figures estimate a 5 percent annual real growth rate for the entire printing industry over the next five years.[3] In addition, total gravure's percentage of the overall graphic arts market is expected to increase from the 14 percent in 1977, to about 16 percent in 1980, and 25 percent in 1990.[4] Therefore, the output of the total gravure industry would be expected to almost double by 1983. However, several constraints (discussed in Chapter 8) such as paper shortages and limited press manufacturing capacity, are expected to decrease this potential growth rate. The result of a more detailed analysis of the growth potential for the publication rotogravure printing industry, as presented in Chapter 8, shows an estimated 7 percent annual real growth rate through the year 1985.

There are several reasons why the rotogravure printing process is experiencing such rapid growth in the publication industry. The primary reason is the result of technological advances in the presses and in the printing cylinder preparation. These advances have greatly improved rotogravure's competiveness with other printing methods for handling shorter run products. In addition, the advantages of rotogravure over other forms of printing are the high quality of the product, the durability of the image surface, and the high volume capability. Gravure is the only printing process in which the amount of ink applied to the paper at

Table 3-1. PUBLICATION ROTOGRAVURE INSTALLATIONS IN THE U.S. AS OF JANUARY 1, 1978

- Alco-Gravure, Inc.
  2436 West 15th Street
  Chicago, Illinois 60608
  312/421-2929

- Alco-Gravure, Inc.
  828 East Holmes Road, Whitehaven
  Memphis, Tennessee 28116
  901/397-7517

- Alco-Gravure, Inc.
  701 Baltimore & Annapolis Blvd, N.W.
  Glenburnie, Maryland 21061

- Alco-Gravure, Inc.
  11041 Vanowen Street
  North Hollywood, California 91605
  213/760-0900

- Arcata Graphics
  696 Trimble Road
  San Jose, California 95150
  408/263-1700

- Arcata Graphics
  Buffalo Division
  TC Industrial Park
  Depew, New York 14043
  716/684-5000

- Art Gravure Corporation of Ohio
  1845 Superior Avenue
  Cleveland, Ohio 44114
  216/861-1750

- Chicago Rotoprint Company*
  4601 Belmont Avenue
  Chicago, Illinois 60641
  312/794-4600
  *W. F. Hall is the parent company.

- Hall of Mississippi Printing Company*
  511 Jackson Street
  P.O. Box 1555
  Corinth, Mississippi 38834
  601/287-3744
  *W. F. Hall is the parent company.

- Dayton Press, Inc.
  2219 McCall Street
  P.O. Box 700
  Dayton, Ohio 45401
  513/268-6551

- The Denver Post, Inc.
  Box 1709
  Denver, Colorado 80201
  303/297-1010

- Gravure West*
  4900 East 50th Street
  Los Angeles, California 90058
  213/583-4101
  *The Denver Post is the parent company.

- Diversified Printing Corporation*
  Box D
  Atglen, Pennsylvania 19310
  215/593-5173
  *Parade Publications, Inc. is the parent company.

- R. R. Donnelley & Sons Company
  2223 South Martin Luther King Drive
  Chicago, Illinois 60616
  312/326-8000

(Continued)

Table 3-1. Continued

- R. R. Donnelley & Sons Company
  Route 30 West
  P.O. Box 837
  Warsaw, Indiana 46580
  219/267-7101

- R. R. Donnelley & Sons Company
  Mattoon Manufacturing Division
  Route 45 North, P.O. Box 189
  Mattoon, Illinois 61938
  217/235-0561

- R. R. Donnelley & Sons Company
  801 Steam Plant Road
  P.O. Box 129
  Gallatin, Tennessee 37066
  615/452-5170

- Kable Printing Company
  404 North Wesley Avenue
  Mt. Morris, Illinois 61054
  815/734-4121

- Meredith Corporation
  1716 Locust Street
  Des Moines, Iowa 50336
  515/284-9011

- Meredith/Burda, Inc.
  4201 Murray Place
  P.O. Box 842
  Lynchburg, Virginia 24505
  804/846-7371

- New York News, Inc.
  Newspoint Gravure Plant
  54th Avenue and 2nd Street
  Long Island City, New York 11111
  212/949-3300

- Providence Gravure, Inc.
  99 West River Street
  Providence, Rhode Island 02904
  401/331-1771

- Texas Color Printers*
  4800 Spring Valley Road
  Dallas, Texas 75240
  214/233-3400
  *Providence Gravure is the parent company.

- Springfield Gravure Corp.
  1940 Commerce Road
  Springfield, Ohio 45501

- Standard Gravure Corp.
  643 South Sixth Street
  Louisville, Kentucky 40202
  502/582-4401

- Triangle Publications, Inc.*
  440 North Broad Street
  Philadelphia, Pennsylvania 19101
  215/665-1350
  *Triangle ceased operations in July 1978.

- World Color Press
  Salem Gravure
  Route #4, P. O. Box 558
  Salem, Illinois 62881
  618/548-4010

any one point can be varied. The gravure method excells for reproducing photographs, fine drawn lines for ads, and separated tones. Modern press speeds, up to about 11 meters per second (2200 feet per minute), greatly facilitate the handling of large production runs.

3.2 FACILITIES AND THEIR EMISSIONS

This study pertains to the volatile organic compounds (VOC) emissions from publication rotogravure printing presses, which are referred to as the "facilities". VOC emissions from ink and solvent storage and transfer facilities, as well as emissions from other printing operations within the same printing plant are not discussed in this document. Additional presses that print other gravure products and different types of printing processes are sometimes housed within the same plant. An attempt to characterize entire printing plants would have dramatically increased the complexity of this study. Therefore, this study involves only those facilities printing publication and advertising products. Air pollutant emissions from the other gravure sectors and from other printing processes may be characterized under future studies.

A typical publication rotogravure printing establishment will consist of two to six production presses and a proof press. Some larger installations have a dozen or more production presses with additional proof presses. Each production press usually consists of eight to twelve individual printing units; proof presses consist of only four printing units. The production presses operate at speeds up to about 11 meters per second (2200 feet per minute); proof presses are usually operated at much slower speeds of about 0.8 to 2.0 meters per second (150 to 400 feet per minute).[5,6] A 1977 estimate indicated that there were about 150 publication rotogravure presses (production and proof), with a total of about 1500 printing units in the United States.[7] Of these, about 125 presses were full-size production facilities.

Proof presses serve as an intermediate testing step between preparation of the printing cylinder and production runs. The proof press is used only to check the quality of the image formation of newly engraved or etched printing cylinders. Therefore, to handle the printing cylinders the proof press must be the same width as the production presses. Proof presses are operated slowly and intermittantly compared to the high speed production presses. The ink and solvents used at proof presses are usually handled out of drums. The total solvent usage by proof presses varies from plant to plant within a range of less than one percent to about two percent of the usage by production presses.[8,9]

The source of the VOC emissions are the solvent components in the inks, extenders, and varnishes used at the printing presses, as well as solvent added for printing and cleaning. The gravure printing method usually involves handling of inks of only the four primary colors of yellow, red, blue, and black. Only one color of ink is handled at each individual printing unit. Any color other than the primary color is produced by printing one primary color ink on top of another to yield the desired mixture. A typical gravure ink consists of pigment, binder, and a solvent. The ink's color is provided by numerous pigment materials such as clay, titanium dioxide, cadium yellows, metallics and flourescents. Various types of resins are employed as binders to lock the pigment to the substrate or web, as well as to protect the pigment from heat, moisture, and abrasion. The extenders or varnishes are sometimes mixed in with the ink to provide a certain texture or glossy effect for the final printed product.

There are two basic types of solvents presently used in this industry. In a few cases only toluene is used. Toluene is usually a better solvent for dissolving the ink resins and for producing a higher quality printed product. On the other hand, toluene is a more expensive solvent and its supply is limited because of the demand from the chemical and fuel-additives industries. The second and most common solvent is a mixture of toluene-xylene-lactol spirits (naphtha). Xylene slows the evaporation rate of the solvent; lactol spirits hasten this evaporation. In areas where highly photochemically reactive solvents are regulated more stringently than are lesser photochemically reactive solvents, and 81-85 volume percent aliphatic, 15-19 volume percent aromatic mixture is commonly used. The aliphatic components frequently function more as reducing agents rather than true solvents.

This industry is researching the possibilities of using low-VOC, waterborne ink systems to reduce their VOC emissions. At present, waterborne inks have not been developed for publication rotogravure printing. One technical problem for waterborne inks is the need for pigments that are more water-soluble than those used now in solvent-borne inks. In addition, waterborne inks tend to form beads on the web surface, rather than sink into the surface as organics do. Also, waterborne inks are more difficult to dry than solvent-borne inks. Drying of the ink is very critical in rotogravure printing because the high speed operation of the presses requires fast and thorough drying of the paperweb between the printing units. Waterborne ink systems are not expected to be developed for this industry for 5 to 10 more years.[10,11]

3.2.1 The Printing Process

Gravure is distinguished from other printing methods by the nature of the image surface. The method is often referred to as the "intaglio" process. An enlargement of the image surface is shown in Figure 3-1. The surface of the gravure printing cyclinder is etched or engraved with many tiny recesses (cells). The depth of each cell determines the amount of ink that will be applied to the paper at that point. The cell depth typically ranges to a maximum of about 35 micrometers [microns] (.0014 inches).

The gravure printing method can be used with two types of printing processes. Rotogravure is the most widely used process. It involves a continuous web of paper that is fed from a continuous roll and passed over the image surface of a revolving printing cylinder. This is known as web-fed or roll-fed gravure. The second gravure printing process, known as sheet-fed gravure, involves the insertion of separate sheets of substrate or paper into a gravure press. Publication and advertising products are printed on web-fed presses only; sheet-fed gravure is not considered in this document.

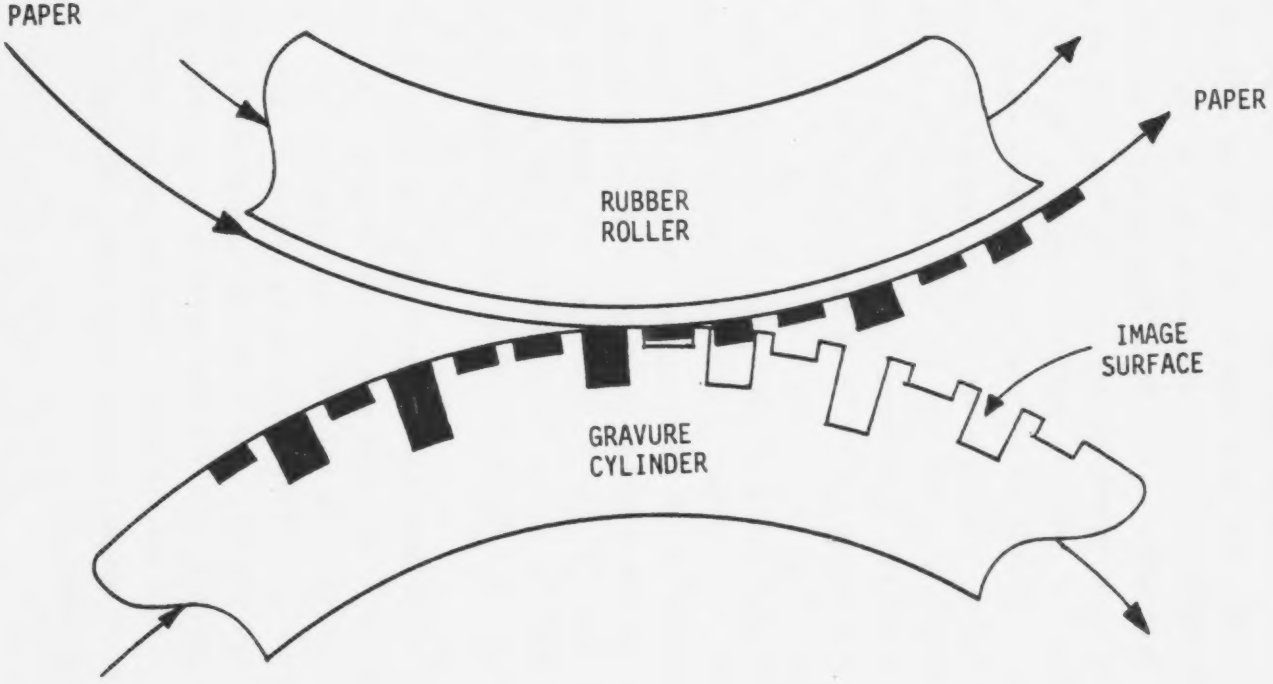
PAPER
PAPER
RUBBER ROLLER
IMAGE SURFACE
GRAVURE CYLINDER

Figure 3-1. Gravure image surface.

The most common web-fed rotogravure printing press consists of eight printing units. A schematic of a typical rotogravure printing press is presented in Figure 3-2. All units of a press must be the same size and width. In addition, all the units must simultaneously operate at the same press speed. However, each unit handles an individual color of ink and prints on only one side of the paper web. Typical press operation consists of printing the four color inks on one side of the web as it passes through the first four units. The web is then guided through four additional units for printing on the reverse side. After leaving the final printing unit, the web is directed to a cutting and folding machine.

The rotogravure press is designed as a continuous printing facility. However, typical operation is probably better described as being semi-continuous. Normal press operation is characterized by numerous shutdowns caused by web breaks or mechanical problems. The frequency and downtime for the press shutdowns varies depending upon the product being printed and the specific cause of the shutdown. Press operating data from several tests is presented in Appendix C.[12,13] The data shows that normal printing operations involve about 6 to 14 press shutdowns per 24 hour period. This yields actual printing times of only about 60 to 85 percent of the scheduled time. Additional downtime occurs at the end of each product run. After completion of the job run, the printing cylinders are removed from each unit. Newly prepared printing cylinders are then installed in each unit for the next job run.

An expanded diagram showing an end view of an individual printing unit is presented in Figure 3-3. The paper web is woven through a series of rollers which precisely adjust its path through the press. The rollers also help regulate the paper tension and maintain constant speed. The web is guided between the revolving gravure printing cylinder and a rubber roller. The paper is pressed against the image surface of the gravure cylinder by the rubber roller, which serves as a backing. Pressure is applied to the rubber roller by a pressure cylinder. The

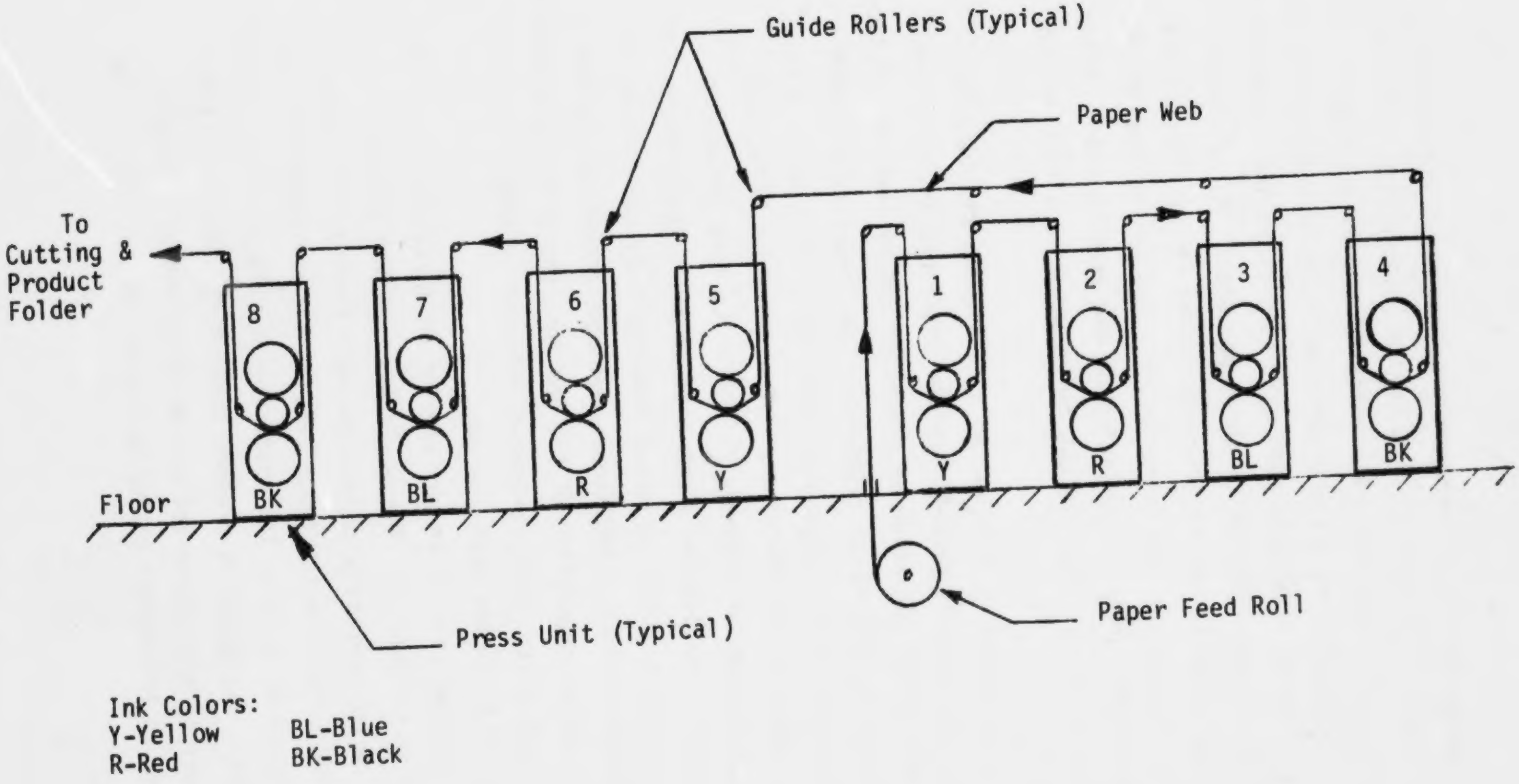
Guide Rollers (Typical)
Paper Web
To Cutting & Product Folder
8
7
6
5
1
2
3
4
BK
BL
R
Y
Y
R
BL
BK
Floor
Press Unit (Typical)
Paper Feed Roll
Ink Colors:
Y-Yellow
R-Red
BL-Blue
BK-Black

Figure 3-2. Schematic of a Typical Eight-Unit Rotogravure Printing Press

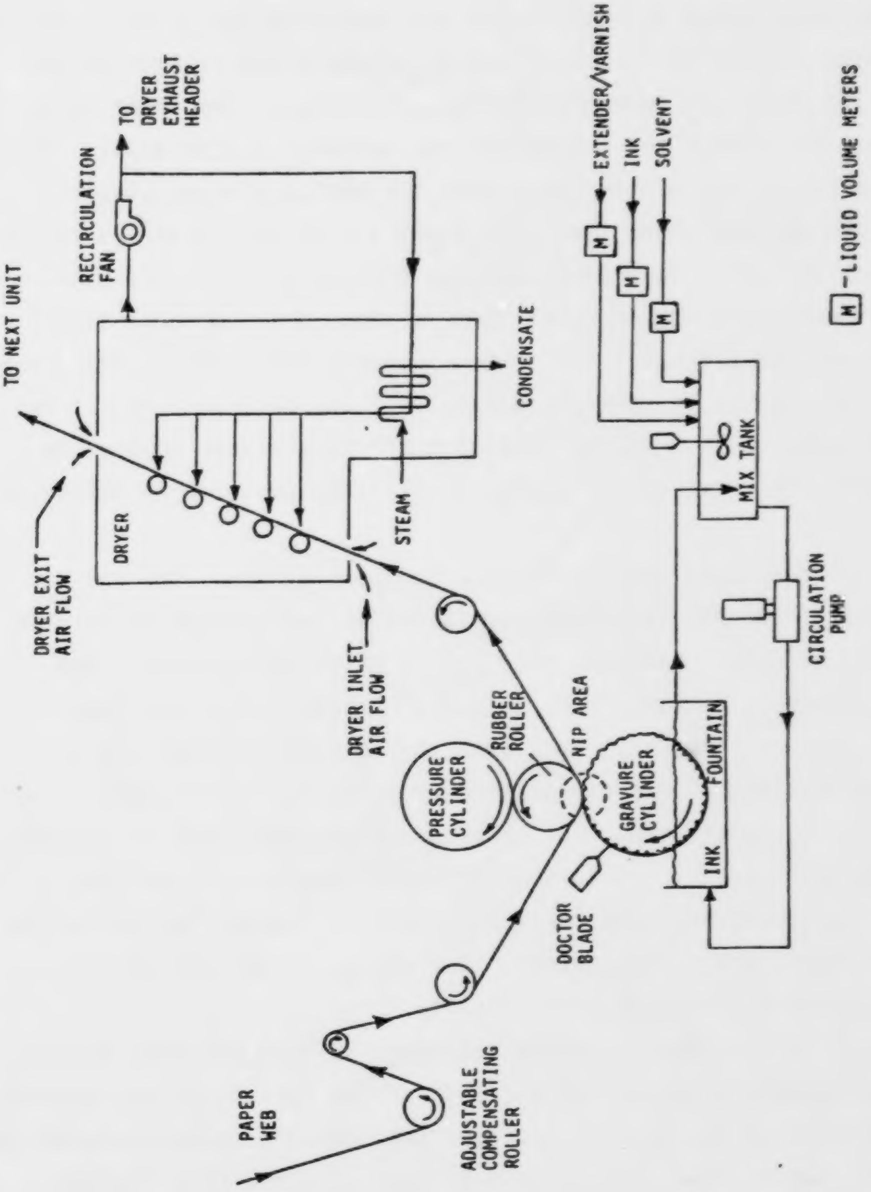
PAPER WEB
ADJUSTABLE COMPENSATING ROLLER
DOCTOR BLADE
PRESSURE CYLINDER
RUBBER ROLLER
NIP AREA
GRAVURE CYLINDER
INK
FOUNTAIN
DRYER INLET AIR FLOW
DRYER EXIT AIR FLOW
DRYER
TO NEXT UNIT
STEAM
CONDENSATE
RECIRCULATION FAN
TO DRYER EXHAUST HEADER
CIRCULATION PUMP
MIX TANK
M
EXTENDER/VARNISH
INK
SOLVENT
M -LIQUID VOLUME METERS

Figure 3-3. Diagram of a rotogravure printing unit.

point of contact between the web and the gravure cylinder is called the "nip" area.

After the impression has been made, the paper web travels up through an enclosed dryer where jets of heated air evaporate the volatile solvent. The web exits the top of the dryer and is guided along rollers to the next printing unit. In modern printing unit designs, the dryer inlet air is drawn in through the bottom and top openings of the dryer. This air is then pulled out of the dryer with the heated air and solvent vapors by the recirculation fan. The dryer air is then directed through a steam heating coil. Most dryer desings contact the heated air on only one side of the paper web; however, some designs dry from both sides. A portion of the fan discharge air is continuously drawn off as the dryer exhaust. In a typically controlled facility, the exhaust from all the dryers are gathered in a header, and directed to a carbon adsorption system. This dryer exhaust is vented to the atmosphere in an uncontrolled plant.

Each printing unit has its own ink handling system. The raw ink is purchased as a concentrated liquid-solid mixture which must be diluted before being used for printing. The ink is mixed with solvent, and sometimes extenders or varnishes, in a mixing tank. The resultant mixture is then continuously circulated through the ink fountain and back to the mix tank. This circulation prevents the ink pigments from settling out of the mixture. The make-up ink and extenders or varnish streams are continuously fed in a controlled ratio to the mix tank by automatic level control. The make-up solvent is usually fed to the mix tank by automatic viscosity control. The amount of solvent addition depends upon the desired ink color density.

The gravure cylinder, on which the image surface has been etched, is about one-fourth submerged in a trough of ink called the ink fountain. Before a portion of the gravure cylinder contacts the paper, it picks up ink from the ink fountain and is then scraped by a flexible "doctor blade". This blade removes the ink from the smooth non-image surface but leaves the ink in the cells.

At the end of each job run, the old image surface is removed from the gravure printing cylinder. A new image is then etched or engraved into the cylinder surface for the next product run. The gravure cylinder is usually made of steel with copper plating. There are several methods presently used to form the image surface. The most common methods are acid etching and electronic engraving. After the image surface has been tested-out and approved on a proof press, the gravure cylinder's surface is then plated with a very thin layer of chrome. This protective chrome plating is much harder than copper and greatly adds to the durability of the image surface.

The ink used for rotogravure printing must instantly fill the cells in the image surface, and therefore must have a relatively low viscosity. This ink mixture, transferred from the cells to paper, must spread on the paper to form printed solid images. The ink solvent to solids ratio as applied to the gravure cylinder varies with the ink type, color, and substrate used. The raw, purchased ink is normally about 50 volume percent solvent. At the press, this ink is diluted with additional solvent at a volume ratio of about 1:1 to achieve a desired viscosity. The resulting mixture is about 25 percent ink resins and solids, and 75 percent solvent. An additional amount of solvent (averaging about 5 percent) is periodically added to the ink fountain to replace evaporated fugitive losses. Therefore, the total equivalent ink mixture used is about 80 volume percent solvent and 20 volume percent ink and varnish solids. A schematic of a general solvent material balance is presented in Chapter 6 for the development of model plant characteristics.

The source of VOC emissions from the publication rotogravure printing presses results from the evaporated solvent used for printing and cleaning. Almost all of the solvent used at the facility eventually vaporizes. Unless this evaporated solvent is captured and controlled, the resultant vapors become air pollutants. A small amount of solvent used at the facility is disposed of as liquid waste ink mixture. This waste ink is usually pumped into drums and is sent out of the plant. In addition, some cleaned-up, used dirty solvent is also disposed of with the waste inks. Some of the solvent used at the press is retained by the printed product. However, this retained solvent eventually evaporates after the printed product leaves the press.

3.2.2 Process Conditions

There are many process conditions to deal with in the publication rotogravure printing industry. Several of these conditions are —

- Cylinder width,
- Cylinder circumference,
- Web width,
- Line speed,
- Dryer temperature,
- Dryer air flow,
- Dryer exhaust VOC concentration,
- Solvent blend,
- Ink type,
- Ink color,
- Ink coverage, and
- Type of paper.

A gravure press is a custom-made machine. When a new press is ordered, the number of units and the cylinder width are specified. The cylinder circumference and the line speed of the press are variable, but the maximum speed is frequently governed by either the mechanical capabilities of the press itself, or the folder. The typical press has eight printing units, although ten and twleve unit presses are common. Cylinder widths range from 1 to 2.7 m (3 to 9 ft.), but a 1.8 m (6 ft) cylinder is quite common. Cylinder circumferences range from about 0.6 to 1.2 m (2 to 4 ft), but average at about 1 m (3.3 ft). Typical press speeds range from 5 to 6 m/s (1000 to 1200 ft/m) for older presses; 9 to 11 m/s (1800 to 2200 ft/m) for newer presses.

The press manufacturer usually supplies the dryer. The design of the dryer depends upon the required drying temperatures, the press speed, and the exhaust air flow. A high boiling solvent requires a higher drying temperature and/or a higher air flow rate. A longer drying path is also sometimes specified. The drying temperature must be carefully controlled to avoid any shrinkage of the web. Web shrinkage is undesirable because it causes web breaks and poor color registration, which results in an off-grade printed product. Drying problems during production runs are usually solved by slight changes in the solvent composition and/or dryer temperatures. The drying temperatures range from ambient to about 120°C (250°F). The black printing units use the highest temperatures. Most of the existing dryer exhaust fan systems are operated at a fixed flow rate and are not adjustable. The air flow rate capacity is usually conservatively designed to allow printing with the maximum expected ink coverage. The dryer exhaust flow rate for each unit ranges from 3400 to 6800 m^3/hr (2000 to 4000 ft^3/min) and depends greatly on the cylinder width and press speed.

Changes in the web width, press speed, and ink coverage influence the dryer exhaust solvent vapor concentration. The dryers are designed with an air recirculation fan to concentrate the solvent vapors in the dryer exhaust. Recirculation fans on most of the existing printing unit dryers are designed only for one constant air flow capacity, in a similiar fashion to the exhaust fan. With fixed air handling capacity systems, a wide press printing on a narrow web could cause excessive dryer exhaust dilution. However, some existing dryers are designed to facilitate throttling and recirculation air flow and provide adequate fresh air makeup, without excessive dryer exhaust dilution. Some of the air throttling controls are manual, while others are automatic. Excessive dryer exhaust dilution requires a larger, more expensive solvent laden air (SLA) capture and control system. The SLA capture and control systems are discussed in detail in Chapter 4.

A very important parameter for dryer operation concerns the lower explosive limit (LEL) of the solvent vapors. The LEL is the lowest vapor concentration in air, expressed as volume percent, at which the mixture could support a flame or explosion at temperatures below 121°c (250°F). Above this temperature, the LEL should be decreased by a factor of 0.7 since explosibility increases with higher temperatures.

Solvent vapor concentrations in the dryer exhaust from most printing units range from about 5 to 20 percent of the LEL. A factor which limits the maximum permissible LEL is frequently the insurance safety regulation. Most facilities are conservatively operated so that the vapor concentrations are maintained well below the 25 percent of LEL maximum recommended safety guideline. Alternatively, solvent vapor concentrations up to 50 percent of the LEL may be allowed if approved continuous vapor-concentration indicator/controllers are used.

Vapor analyzers can be installed in the dryer exhausts for maximizing the solvent vapor concentrations.[14,15] These analyzers control the organic vapor concentration to a certain set point by automatically regulating the amount of exhaust air drawn from the dryers. An alarm can be installed to sound if the vapors in the collected exhausts reach a certain maximum desired level, or the vapors in any of the individual dryer exhausts reach about 40 percent of the LEL. Additional safety features can include automatic press shutdown if the vapor concentration should reach about 50 percent of the LEL.

The percent ink coverage for a specific ink color is defined as the percentage of maximum positive density for that specific ink. The maximum possible ink coverage for a four-color product (total coverage for each of four colors) is 400 percent. Typical total ink coverages range from less than 100 percent to 300 percent for a spot on a four-color product. If the ink coverage increases, the dryer exhaust may become more concentrated with VOC. If, however, the ink coverage decreases, the dryer exhaust may become less concentrated.

The color and type of ink can affect the VOC concentration in the SLA from the various printing units. Each unit uses a different color of ink for one side of the printed product. Each color and type of purchased ink has a different solvent content. The solvent content ranges from about 30 to 70 volume percent, but averages 50 volume percent. The dilution solvent used for the inks is all the same, but the amount required varies depending on the varnish and resin content. The typical solvent content of the mixed ink ranges from 70 to 85 volume percent, but averages 75 percent. Consequently, the solvent content of the mixed ink (as printed) varies from unit to unit. This variation can affect the SLA concentration from each unit's dryer.

The type and quality of paper used can affect the maximum practical press speed. Excessive press speeds with poor grades of paper can cause frequent web breaks. Web breaks can create a significant amount of unscheduled down time, and are therefore undesirable. The coated paper stock (used in high quality magazines and advertisements) is more difficult to dry, and therefore sometimes requires greater dryer air flow rates.

Test data presented in Appendix C shows that publication rotogravure presses have unscheduled shutdown frequencies ranging from 0.2 to 0.7 shutdowns per press hour. Typical run times range from one to three hours, with maximum run times exceeding four hours. The individual presses at one tested plant were running about 64 to 86 percent of the total test time.[16] Presses at another plant were operating about 72 and 78 percent of the time.[17]

3.2.3 Fugitive Emissions

Figure 3-4 presents a side or end view of a typical printing unit, showing the locations where fugitive vapors can escape. The main sources of fugitive vapors result from solvent evaporation in the ink fountain, the exposed part of the gravure cylinder, the paper path from the printing nip to the dryer inlet, and from the paper after exiting the dryer. In some installations the nip area and ink fountain are exposed, and the dryer inlet and exit openings are large. The proximity of the dryer inlet to the nip area also varies with each press. On newer presses, these fugitive vapors are minimized by enclosing the ink fountain, extending the bottom of the dryer down closer to nip area, and providing only small slit openings for the web entrance and exists.

A small amount of solvent is retained in the finished product. The amount of this retained solvent may vary from about 1 to 7 percent of the total solvent used at the press, depending on the type of paper and type of ink used.[18,19,20,21] An industry study has estimated that an average of 2.5 percent of the solvent used remains in the printed product.[22]

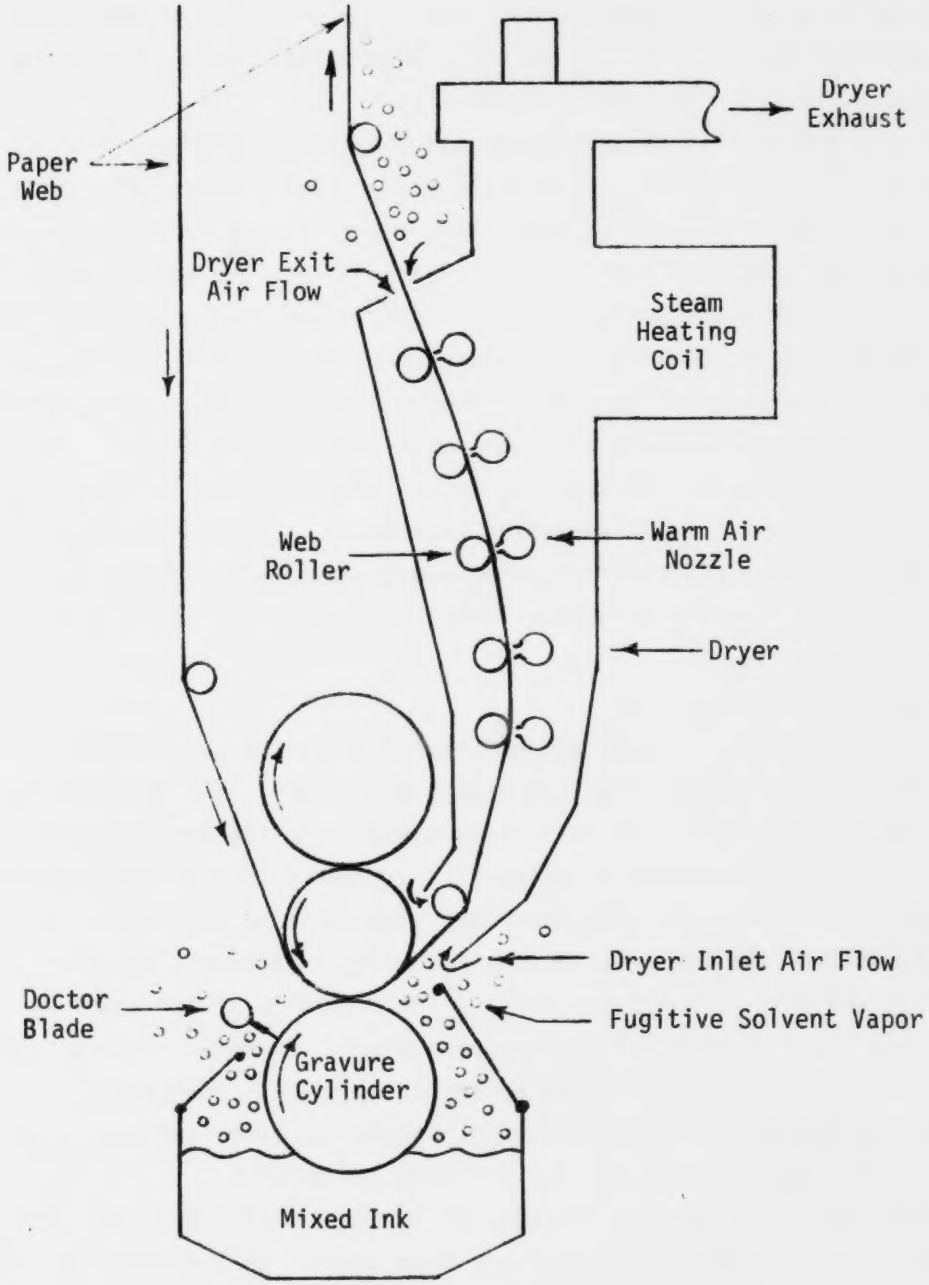
Dryer Exhaust
Paper Web
Dryer Exit Air Flow
Steam Heating Coil
Web Roller
Warm Air Nozzle
Dryer
Dryer Inlet Air Flow
Doctor Blade
Fugitive Solvent Vapor
Gravure Cylinder
Mixed Ink

Figure 3-4. Fugitive solvent vapor emissions around a gravure publication printing unit.

One firm estimates a 3 percent retention.[23] At present there is no known reliable method for determining the exact amount of retained solvent.[24] In general, a product printed with a glossy ink and varnish retains more solvent than does a product printed with a non-gloss ink. This solvent is eventually emitted to the atmosphere. Careful operation of the dryers should minimize the retained solvent. However, it is not possible to completely eliminate all retained solvent.

The quantity of fugitive emissions and dryer exhaust emissions is directly related to the amount of ink used. The amount of ink used depends on the percent of ink coverage on the product, the press speed, and the operating time. The percent of ink coverage and the amount of running time may vary widely. A typical press operation consists of periodic shutdowns due to web breaks, mechanical problems, and cylinder cleaning.

An efficient SLA capture system must be able to adapt to varied conditions of shutdown and startup and printing operation. The vaporization rate of solvent from a printing unit is greatly reduced when the press is shut down. The shutdown mode further complicates efficient SLA capture because the SLA stream approaches room temperature during shut down mode. The cooler solvent fumes during shut down mode tend to settle near the lower part of the pressroom. These cool fumes can be effectively removed with floor sweep ventilators. However, during normal operation, the warm solvent fumes rise. These warm fumes are most efficiently collected in the mid to upper part of the pressroom, in the press area. Floor sweeps are not very effective in removing the warm solvent fumes, which are generated during normal operation.

Fugitive emissions can be minimized by —

- Enclosing the ink fountain,
- Reducing the distance between the dryer inlet and the nip area,
- Improve vapor capture at the entrance and exit of the dryer,
- Thorough drying of the web in each dryer, and
- Increased solvent vapor capture in the upper and lower areas of the press.

3.3 BASELINE EMISSIONS

The baseline emission level is the level of emission control that is achieved by the affected industry in the absence of additional EPA standards. A recent guidelines document, issued by EPA recommends that states with oxidant non-attainment areas revise their implementation plans to provide an emission reduction of 75 percent from existing publication rotogravure plants.[25] New plants in these areas will be subject to at least this level of control. In most attainment areas, new plants will be subject to emission limitations to prevent significant deterioration. In the few areas where state restrictions will not apply, it seems logical that this industry should want to recover some of the solvent used. Solvent supplies are closely related to gasoline and other fuel supplies, which will become less available and more expensive in the future. A general material balance presented in Chapter 6 shows that this industry would probably want to control at least 75 percent of their potential VOC emissions, and recycle the recovered solvent. For these reasons a baseline control level of 75 percent was chosen as the level to which new publication rotogravure plants would be controlled in the absence of new source performance standards.

Table 3-2 summarizes state emission regulations which apply to the present rotogravure printing industry. Many state regulations for stationary sources of organic solvent are similar to Los Angeles Rule 66, which allows an emission of 40 lb/day of "photochemically" reactive solvent and 3000 lb/day of "non-photochemically" reactive solvent. However, most states exempt "non-photochemically" reactive solvents from control regulations.[26] A "non-photochemically" reactive solvent is usually defined as one in which highly photochemically reactive content is less than 20 precent and that of aromatic organic solvents with more than 8 carbons is less than 8 percent. Several states have no volatile organic emission standards.[27,28] Photochemical reactivity is discussed further in Chapter 7.

TABLE 3-2. STATE AIR POLLUTION REGULATIONS FOR ORGANIC SOLVENT EMISSIONS WHICH APPLY TO THE PUBLICATION ROTOGRAVURE PRINTING INDUSTRY

	Non-exempt[a]	Exempt[b]	Exceptions
California (Los Angeles)	18 kg/day, 3.6 kg/hr (40 lb/day, 8 lb/hr)	3000 lb/day, 450 lb/hr	Unless controlled 85 percent
Colorado	18 kg/day, 3.6 kg/hr (40 lb/day, 8 lb/hr)	3000 lb/day, 450 lb/hr	Unless controlled 85 percent
Illinois	3.6 kg/hr (8 lb/hr)	8 lb/hr if odorous	Unless controlled 85 percent, no controls for exempt
Indiana	6.8 kg/day, 1.4 kg/hr(15 lb/day, 3 lb/hr)		Unless controlled 85 percent, no controls for exempt
Iowa			No volatile organic compound standards
Kentucky	18 kg/day, 3.6 kg/hr (40 lb/day, 8 lb/hr)		Unless controlled 85 percent by weight, no controls for exempt
Maryland	18 kg/day, 3.6 kg/hr (40 lb/day, 8 lb/hr)		No controls for exempt
Mississippi			No specific volatile organic compound controls
New York	(Regulations specific to pollutant, site, volume, etc.)		
Ohio	18 kg/day, 3.6 kg/hr (40 lb/day, 8 lb/hr)		Unless controlled 85 percent, no controls for exempt
Pennsylvania			No volatile organic compound controls
Rhode Island	18 kg/day, 45 kg/day/site (40 lb day, 100 lb/day/site)		No controls for exempt
Tennessee	(Regulations specify "Reasonable & Proper Technology")		
Texas	45 kg/hr (100 lb/hr)		No controls for exempt
Virginia	18 kg/day (40 lb/day)		Unless controlled 85 percent, no controls for exempt

a Photochemically reactive solvent
b Low- or non-photochemically reactive solvent

According to an industry survey, 82,000 Mg (90,000 tons) of ink were used by the publication rotogravure industry in 1976.[29] Considering the growth rate of the industry, an ink usage of 91,000 Mg (100,000 tons) for 1977 was estimated. The purchased ink typically averages about 50 volume percent solvent, and is mixed on a 1:1 volume basis with additional solvent. Thus, approximately 136,000 Mg (150,000 tons) of solvent was estimated to have passed through publication rotogravure presses in 1977. An accumulation of information obtained from numerous sources indicated that the total solvent usage was about 137,300 Mg (151,190 tons).[30] A small amount of additional solvent was used for cleaning.

This entire 137,300 Mg (151,190 tons) of solvent would have been emitted to the atmosphere if no control devices were used by the industry in 1977. However, information from numerous sources indicated that only about 56,800 Mg (62,570 tons) were emitted.[31] Approximately 80 percent of these emissions were from uncontrolled sources. Thus, almost 60 percent of the solvent used was recovered. In most cases, the recovered solvent was recycled by the printing plants; some solvent was sold back to ink manufacturers.

In an uncontrolled plant, none of the volatile solvents are recovered. The dryer exhaust is vented directly to the atmosphere. Most of the fugitive solvent vapors are removed from the press areas through room vents by roof and peripheral vents fans. The fans ventilate the working areas by maintaining a negative pressure in the press room. The resulting solvent concentration in the pressroom air is maintained below the OSHA standards, which is 200 PPM for toluene.[32]

Nineteen of the 27 installations that were operating in 1977 were using carbon adsorption systems to recover the solvent vapors from at least one press. In a typical solvent recovery installation only the dryer exhausts are treated by the carbon adsorption system. Appendix C shows data from two plants which recover 75 to 85 percent of the solvent used, by just capturing the dryer exhausts. At some facilities, fugitive vapor pickups are installed as local capture points to prevent the formation of pockets of solvent laden air around the presses. However, roof and peripheral vent fans may still be required to keep the solvent concentration in the pressroom air below the OSHA regulations.

An apparent overall recovery efficiency of greater than 90 percent has been demonstrated at one facility.[33] At this facility careful attention was given to the design details of the solvent vapor capture system, as well as to the control device, to achieve the high overall recovery efficiency. All vents are routed to the solvent recovery system. The web path through the units is essentially contained. The major solvent losses here are fugitive emissions associated with solvent retention in the printed product. Additional emissions result from the adsorber exhaust. Typical average treated exhaust concentrations range from 10 ppm to 100 ppm, with occasional breakthrough concentrations reaching several hundred ppm. Chapter 4 provides a more detailed discussion on the VOC emission control techniques, which apply to this industry.

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4. EMISSION CONTROL TECHNIQUES

This chapter discusses techniques used for controlling volatile organic compound (VOC) emissions from publication rotogravure printing presses. The chapter begins with a general discussion on existing and alternative emission control systems. EPA emission test results and industry plant data for several existing control systems are then presented. Finally, discussions on solvent vapor capture systems, solvent recovery systems, and solvent destruction systems are presented.

4.1 OVERALL EMISSION CONTROL

4.1.1 General

The complete air pollution control system for a modern publication rotogravure printing facility consists of two discrete sections: the capture system and the emission control device system. The capture system is designed to gather the volatile organic compounds (VOC) vapors emitted from the presses. The captured vapors are then directed to an add-on control device. The overall reduction efficiency for VOC emission control systems is equal to the capture efficiency times the control device efficiency.

Carbon adsorption is the only method currently being used to control solvent vapor emissions from the presses. Multiple fixed-beds, operating in parallel configurations, regenerated by steaming, represent the typical case. A new adsorption technique using a fluidized-bed of carbon may be used in the future. Solvent recovery is usually an integral part of both types of carbon adsorption systems. Solvent destruction (i.e. oxidation) systems are also available for control of VOC vapor emissions. However, these systems destroy the valuable solvent vapors. The actual printing operation is not ordinarily affected by the emission control system.

As an alternative emission control technique, this industry is researching the possibilities of using low-VOC, waterborne ink systems to reduce their VOC emissions. However, only solvent-borne ink systems are presently used, as explained in Chapter 3.

A flow diagram showing where the VOC solvent enters and leaves a controlled printing facility using solvent recovery is presented in Figure 4-1. Liquid solvent enters the facility as part of the inks, varnishes and extenders used, as well as solvent added for printing and cleaning. Some of the solvent leaves the press as uncaptured fugitive vapor emissions. The printed product retains about three percent of the total solvent used at the press, as mentioned in Chapter 3. Recovered waste solvent from cleaning operations and any waste inks are sent out of the plant to be reclaimed. The adsorber outlet vapor losses depend on the capture-air flow rate and the adsorber efficiency, which is discussed in a later section. A waste water stream containing dissolved solvent results from the condensation of steam which is used to regenerate the carbon beds. Test data presented in Appendix C show that dissolved solvent discharged with the condensate represents less than 0.1 percent of the total solvent used at the press. The recovered liquid solvent from the captured vapors is metered and recycled for use as solvent addition. Any excess recovered solvent can be sold as a by-product.

Most new rotogravure printing plants install liquid volume meters to measure the amounts of inks, extenders/varnishes, and solvent input to each printing unit of the press. A meter also measures the volume amount of recovered solvent. These meters are installed for process control and customer billing purposes. Moreover, they provide a basis for measurement of the overall solvent loss. The liquid meters currently installed in this industry operate by several variations of the positive displacement type principle. Manufacturer's data on some of the liquid meters used for the inks, extenders and varnishes provide accuracies ranging from ±1.0 percent to ±1.5 percent.[1,2] The data on meters used for solvent addition at the press and recovered solvent show accuracies ranging from ±0.2 percent to ±1.0 percent.[3,4,5,6] The manufacturers recommended that the meters be recalibrated at least every six months.[7]

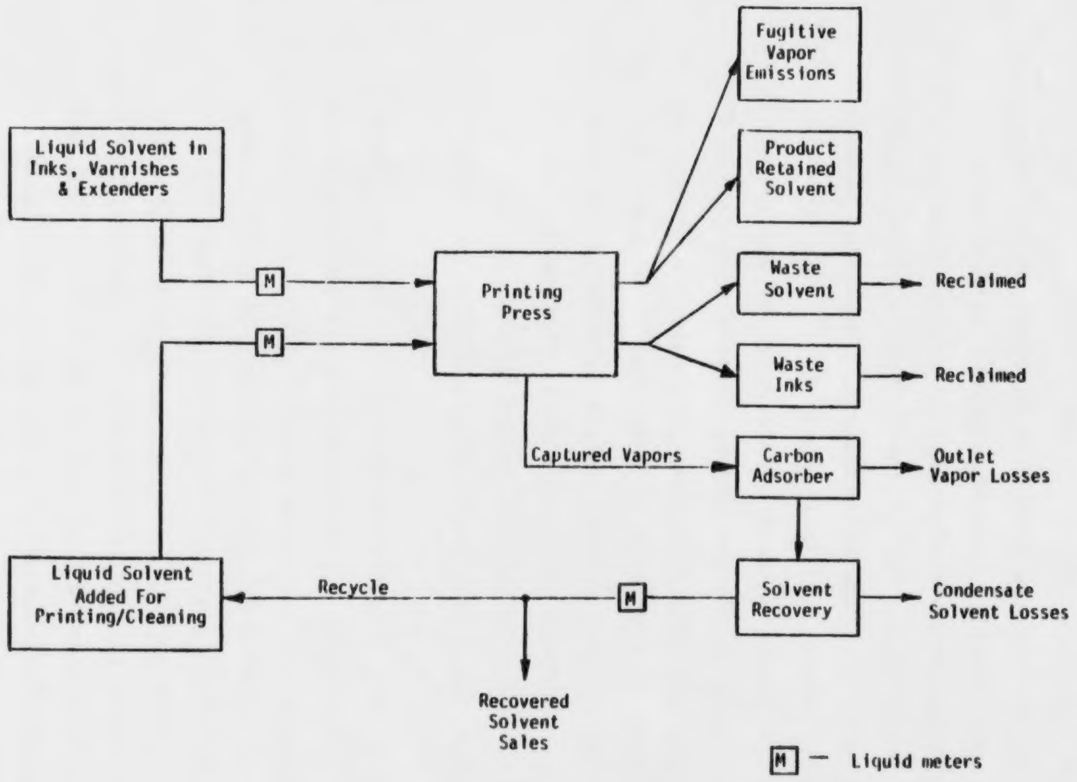
Liquid Solvent in Inks, Varnishes & Extenders
Liquid Solvent Added For Printing/Cleaning
M
M
Printing Press
Fugitive Vapor Emissions
Product Retained Solvent
Waste Solvent
Waste Inks
Reclaimed
Reclaimed
Captured Vapors
Carbon Adsorber
Outlet Vapor Losses
Solvent Recovery
Condensate Solvent Losses
Recycle
M
Recovered Solvent Sales
M — Liquid meters

FIGURE 4-1. Solvent flow around a publication rotogravure printing press with carbon adsorption/solvent recovery.

4.1.2 Performance Data

The performance of existing VOC emission control systems in this industry was demonstrated during short-term tests at facilities in two plant sites: Meredith/Burda, Inc. (Phase III facilities) and Texas Color Printers, Inc. The performance data were obtained during only a few days of testing at each facility. Three separate methods were employed to determine the operating performance of the emission control systems at both tested facilities. Two of the methods involved vapor phase analyses combined with air flow measurements. These two methods are discussed in the test reports and in Appendix C.[8,9] The third method involved an overall liquid solvent volume material balance utilizing the liquid meters, combined with the ink manufacturer's data on the VOC volume content of the inks and extenders/varnishes used. A comparison of the results of the three test methods is presented in Appendix C. The results showed that the liquid solvent volume balance is the most accurate, reliable, and convenient method for determination of overall VOC emission reduction. Thus, the solvent volume balance method was used to report and compare the performance results of the two formal tests.

Long-term plant data were obtained in addition to the short-term test data. Discussions in Chapter 3 concerning the variability of the rotogravure printing process and the wide range of products handled suggest that short-term test data may not be adequate to project long-term emission control performance in this industry. Consequently, several months (and four-week periods) of plant data showing the long-term performance of VOC emission control systems were obtained from both tested facilities, as well as several non-tested facilities. The long-term data were obtained by plant personnel using an overall liquid solvent balance method on a volume basis, except at Standard Gravure, Inc. where a weight-based solvent balance is employed.

The typically controlled facilities, which capture only the dryer exhausts, achieve overall VOC control efficiencies ranging from 75 to about 84 percent. VOC emissions from existing, older presses are controlled at only the efficiency levels in the lower end of this range to recover enough solvent for re-use at the presses. However, newer presses controlled by modern adsorber systems can achieve the higher control levels at the upper end of the range. Overall emission reductions of 80 to 84 percent were determined from short-term tests conducted at the Texas Color Printers plant.[10,11] In addition, five months of plant data obtained from Texas Color showed an average overall control efficiency of about 81 percent.[12] Also, over four months of plant data from World Color Press showed 4-week average overall control efficiencies ranging from 78 to 84 percent.[13] A summary of these data is presented in Appendix C.

The best controlled facilities capture some of the fugitive solvent vapors, as well as the dryer exhausts. Reported long-term plant data from a few non-tested facilities show overall VOC reduction efficiencies ranging from 82 to about 90 percent. Triangle Publications reported plant data ranging from 82 to 87 percent overall control.[14] Several other plants reported VOC emission control in the 87 to 90 percent range.[15,16,17] However, the most reliable performance data for the best demonstrated VOC emission control systems were obtained for facilities at the Meredith/Burda (Phase III), Standard Gravure, and Texas Color plants. Table 4-1 presents a performance data summary for these three controlled facilities showing overall reduction efficiencies ranging from 84 to 93 percent.

The first data source presented in Table 4-1 is the Meredith/Burda plant. Toluene is the solvent used at these facilities. Apparent overall control efficiencies of greater than 90 percent were demonstrated in short-term tests at the newest facilities in this plant.[18] In addition, data were obtained from this plant for ten separate months, indicating apparent overall control efficiencies greater than about 89 percent.[19,20,21]

Several representatives of this industry have asserted that 90 percent overall control is not achievable. Their comments pointed out several "unique features" and possible problems with the newest Meredith/Burda facilities.[22,23,24] Supplemental sampling was conducted at that plant to acquire more data regarding some of industry's comments.[25] The

TABLE 4-1. DATA BASE SUMMARY OF BEST DEMONSTRATED OVERALL VOC EMISSION CONTROL SYSTEM PERFORMANCE IN THE PUBLICATION ROTOGRAVURE PRINTING INDUSTRY.

Data Source (year)	Performance Averaging Periods	Overall Solvent Recovery Efficiency, %	
		Apparent Average	Adjusted Average[a]
Meredith/Burda (Phase III):			
- Short-term EPA tests (1978)	26-51½ hours	94-97	89-92
- Long-term plant data (1979-1980)	10 individual months	89-96	84-91
Standard Gravure:			
- Long-term plant data (1979-1980)	15 four-week periods	85-90	---
- 1975 Technical paper[b] (1973-1974)	104 week periods	90	---
Texas Color:			
- Calculated potential from short-term EPA tests (1979)	13½-82 hours	90-93	---
- Calculated potential with combined long-term plant data (1979)	one 5 month period	88-90	---

[a] 5 percent total efficiency adjustment for Meredith/Burda data: 2 percent temperature correction factor for recovered solvent; 3 percent factor for infiltration of solvent vapors. No adjustment required for data from other sources.

[b] Reference 29.

results of the supplemental measurements are summarized in Appendix C. Consideration of industry comments and a thorough evaluation of the Meredith/Burda test results and supplemental measurement results show that the apparent overall control efficiencies should be adjusted downward by about five percent to compensate for two characteristics.

- A two percent factor is required for the density variation caused by the differences in temperature between the recovered toluene solvent and the raw inks and toluene used at the presses. To obtain a true overall solvent material balance, the direct volumetric reading of the recovered solvent meter must be corrected to compensate for the density difference (see Appendix C).[26,27,28,29,30,31,32,33,34]
- A three percent factor is required for infiltration of solvent vapors from other pressrooms in the plant.[35]

In addition, industry representatives mentioned that some other plants in this industry could not consistently achieve even the adjusted overall control levels demonstrated at Meredith/Burda. The following three reasons were cited for the expected lower overall control performance.

- The highly effective solvent vapor capture system design employed at Meredith/Burda may not be usable by some facilities because of potential OSHA worker exposure violations (See section 4.2.1).
- Some printed products retain more solvent than others -- the more solvent retained, the less vapor that can be captured and recovered.
- Meredith/Burda handles special long run products, while most other plants print shorter run products--the shorter run products cause more frequent web breaks and press shutdowns during printing, as well as more press down-time between job runs--the capture efficiency may be lower with the resulting more dilute solvent laden air decreasing the adsorber efficiency when handling the shorter run products.

The second data source is the Standard Gravure plant. Naphtha-based mixed solvents are used at these facilities. This plant is regarded as having the most thorough capture system; however, the system requires handling and treatment of much larger amounts of solvent laden air (SLA) than the capture system at Meredith/Burda. Tests were not conducted at this plant site because the capture system did not appear to be as economical as the one at Meredith/Burda. Long-term, four-week average overall control efficiencies reported by Standard Gravure range from 85 to 90 percent.[36,37] In addition, a longer-term study conducted at these facilities after the initial installation showed a 90 percent average overall control level on a weekly basis.[38] No adjustment to these reported plant data are necessary.

The third data source is the Texas Color plant. Naphtha-based mixed solvents are also used at these facilities. As previously mentioned, only dryer exhausts are captured at these tested facilities. During the short-term tests, gas phase monitoring results showed that the pressroom ventilation SLA discharged to the atmosphere accounted for about eight percent of the total solvent volume used at the presses. Calculations show that overall solvent recovery efficiencies exceeding 90 percent could potentially be achieved if the pressroom ventilation air were directed to the control device rather than to the atmosphere. However, combination of the short-term test data with five months of plant data indicated potential overall solvent recovery efficiencies of only about 88 to 90 percent. The lowest calculated potential efficiency, in each case, was based on a one percent decrease in adsorber efficiency which would result from the 30 percent increase in the captured SLA flowrate. The highest calculated potential efficiencies would correspond to increased adsorber efficiencies from modification and better instrument controls comparable with those at Meredith/Burda. These potential cases are tabulated in Appendix C.

In conclusion, the performance of the best demonstrated emission control systems in the publication rotogravure printing industry are influenced by many factors which cause a wide range of overall efficiency results. It appears that 90 percent overall control is achievable under some conditions, but not on a long term basis. The highest achievable long-term average overall VOC control efficiency is about 85 percent; although, the performance may drop to about the 84 percent level during one or two months throughout a year of operation. These lowest achievable efficiencies account for periods of low solvent usage, solvent retention in the product, and printing of products that cause frequent production delays. These three factors are discussed in more detail in the following sections.

4.2 SOLVENT VAPOR CAPTURE SYSTEMS

4.2.1 System Descriptions

Existing solvent vapor capture system designs vary considerably. Most plants capture only the dryer exhausts. In addition, a few facilities have floor sweeps or pressroom vents near each press to capture some of the fugitive solvent vapors. However, the most effective system designs attempt to capture all of the solvent laden air (SLA) that leaves the pressroom.

The capture efficiency of the dryers is limited by their temperature and the operating speed of the newer presses. Dryer temperatures range from ambient to about 120°C (250°F), as discussed in Chapter 3. The higher temperatures in this range can only be used on the units printing with black ink. Higher temperatures impair product quality and increase the frequency of web breaks. The increasing operating press speeds of modern presses of over 10 m/s (2,000 fpm) limit the web's residence time in the dryers. Thus, significant amounts of fugitive solvent vapors are emitted from the presses because of the limited dryer capture efficiency.

The dryer exhaust SLA vapor concentration level greatly influences the required size of the adsorber system. Modern high velocity dryers are usually equipped with integral drying air recirculation fans to concentrate the dryer exhaust and minimize the amount of SLA. Vapor analyzer control systems can be installed on the printing unit dryers to safely increase the exhaust solvent vapor concentrations. The lower explosive limit (LEL) for rotogravure solvent vapors range from about 9,000 to 12,700 ppmv. Thus, the dryer exhaust vapor concentration level would have to be lower with some solvents than others. Insurance requirements limit the normal maximum allowable vapor concentration to about 50 percent of the LEL. Thus, the maximum operating vapor concentration could probably be as high as 30-40 percent of the LEL, or 2,700 to 4,800 ppm (V/V). From short-term test data, the Meredith/Burda dryer exhaust levels were calculated to be about 2,300 ppmv toluene vapors. This represents a level of almost 19 percent of the toluene LEL; equivalent concentrations with vapors from naptha based solvents would represent about 26 percent of the LEL.

Facilities that capture only the dryer exhausts must install some type of pressroom ventilation fans that discharge to the atmosphere. These fans are necessary to remove the fugitive solvent vapors from the press-room. The solvent vapor concentration in the pressroom air must be kept below the level of OSHA regulations. The present OSHA time-weighted average (TWA), 8-hour exposure limit for toluene vapors is 200 ppmv. The allowable vapor concentration limits for the components of the naphtha based mixed solvents range from 100 ppmv up to 500 ppmv as shown in Chapter 7. OSHA has a proration formula for determining compliance with vapor component mixtures.

A highly efficient capture system is necessary to achieve high overall emission reduction efficiencies. Fugitive solvent vapors, as well as the concentrated dryer exhausts must be captured. Some of the fugitive solvent vapors result from evaporated solvent in the ink fountains, from the exposed part of the gravure printing cylinder, and exposed portions of the paper web before entering the dryers. Enclosed ink fountains and extended enclosed dryer designs of newer presses help to minimize the escape of fugitive vapors from these locations during press operation. However, these areas must be uncovered to obtain access to the press during shutdowns for web breaks, cylinder changes, or maintenance items. The major source of fugitive vapors from newer presses during operation is the paper web after exiting the dryers. Fugitive vapors are emitted from this source even during press shutdowns. In addition, as discussed in Chapter 3, the final printed product retains about one to seven percent of the solvent used at the press, and continues to be a source of fugitive vapors from the cutting and folding areas after leaving the press.

Three types of capture systems were evaluated. The first type, demonstrated at the facilities of Texas Color Printers, Inc., captures only dryer exhaust vapors, while pressroom ventilation air is discharged to the atmosphere. Naphtha-based mixed solvents are used at these tested facilities. Test data for this capture system show that about 900 to 1,000 SCFM of ventilation air are required for each printing unit; while the dryer exhaust for each printing unit accounts for about 2,300 to 2,400 SCFM of air.[39] The amount of ventilation air thus required to remove fugitive vapors represents about 30 percent of the total amount of air removed from the pressroom.

A second type capture system was demonstrated at the newest facilities of Meredith/Burda, Inc.[40,41] Toluene is the solvent used at these tested facilities. Fugitive vapor cabin enclosures are installed over the top portion of the printing presses. A schematic of such an enclosure, installed over the top portion of an eight-unit printing press, is presented in Figure 4-2. Fume pickup nozzles located on the bottom of the cabin draw in enough air to keep the pressroom at a slightly negative pressure. Since the air surrounding the press has a higher solvent vapor content that the average pressroom air, minimal air makeup is required to satisfy OSHA regulations. This is because the solvent vapors surrounding the press units are drawn into the cabin before they can propagate throughout the pressroom. In addition, fugitive vapors from evaporated solvent leaving the paper web between printing units are also captured. The captured fugitive solvent vapors are then pulled out of the cabin through multiple vents, directed along with the dryer exhausts from each printing unit, and sent to a carbon adsorption system. One or more large SLA fans provide the motive force for pulling the air through the cabin enclosures and printing unit dryers. Pressroom ventilation fans are not installed at these facilities. Wall or ceiling vents could be added to increase the capture efficiency of fugitive vapors, if more stringent OSHA regulations become necessary. Test data from the Meredith/Burda facilities show that approximately 900 SCFM of air per printing unit are pulled through the cabin enclosures.[42] This fugitive VOC capture air

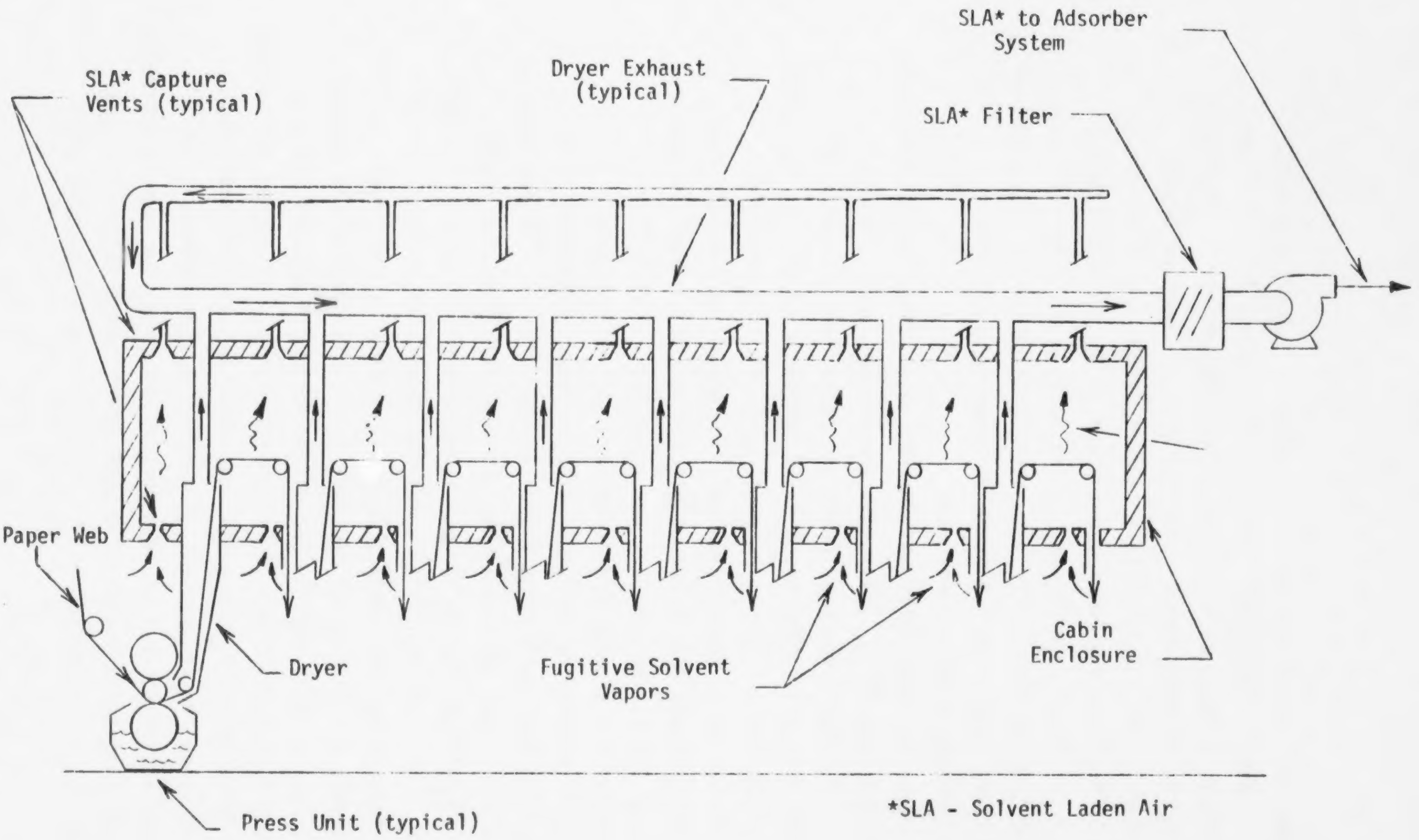
SLA* to Adsorber System
SLA* Capture Vents (typical)
Dryer Exhaust (typical)
SLA* Filter
Paper Web
Dryer
Fugitive Solvent Vapors
Cabin Enclosure
Press Unit (typical)
*SLA - Solvent Laden Air

Figure 4-2. Cabin enclosure system for fugitive solvent vapor capture around a typical eight-unit publication rotogravure printing press.

flow represented about 30 percent of the total air handled by the control device system.

On a theoretical basis, a fugitive vapor cabin enclosure design should not pose any risk of excessive worker exposure to solvent vapors which would constitute an OSHA violation. Solvent (toluene) vapor concentrations were measured inside the Meredith/Burda cabin enclosures during the short-term tests and again during supplemental sampling tests. During printing operations, the measured toluene vapor concentrations ranged from about 300 ppm to over 1,000 ppmv.[43,44] However, the cabin enclosure is not a normal work area during printing operations. Operators enter the cabins only during press shutdowns. When a press shutdown occurs (e.g., for a web break) the generation rate of solvent vapors greatly decreases, but pressroom air is still pulled through the cabin enclosures. Therefore, if enough purge time is allowed, the cabin enclosure environment should reach equilibrium with the pressroom ambient solvent vapor concentration. Adequate purge time is determined by the volumetric air purge rate and the ambient solvent vapor concentration in the pressroom air. Theoretical calculations, presented in Appendix C, using measured volumetric air purge rates show that an initial 1,000 ppmv cabin enclosure toluene vapor concentration should be decreased to below the OSHA 8-hour TWA limit in about one to one and one-half minutes after press shutdown, assuming respective ambient pressroom vapor concentrations of 50 to 150 ppmv. It should be noted that the measured air purge rates during the Meredith/Burda tests were only at about 70 percent of the 17,000 Nm^3/hr (10,000 SCFM) design air flow rate. The required purge time to meet the OSHA 8-hour TWA toluene limit would be reduced by about 30 percent at the design air purge rate. Therefore, for well designed cabin enclosures and normal ambient pressroom solvent vapor concentrations, about one minute of purging should be required before operators could safely enter the enclosure.

Direct application of the demonstrated Meredith/Burda cabin enclosure design may, however, present difficulties in meeting some OSHA regulations. Toluene vapor concentrations inside the enclosures were measured to be as high as 200 to over 300 ppmv, during press shutdowns.[45,46] These vapor concentration levels are within the ceiling limits of OSHA regulations; however, repeated exposure to these high concentrations, combined with pressroom ambient vapor concentration levels may cause some press operators to be exposed in excess of the 8-hour TWA limit. One major reason for the high shutdown vapor concentrations is that the newest pressroom ambient vapor concentrations were measured at about 100 to over 200 ppmv.[47] In comparison, ambient toluene vapor concentrations were measured to be only 20-60 ppmv in other pressrooms and plant areas with ventilation fans discharging to the atmosphere.[48] A second major reason for the high shutdown vapor concentrations is the maldistribution of air flow through the cabins. In addition, Meredith/Burda handles larger volume print orders than some other printers in this industry. Some of the shorter-run products not handled by Meredith/Burda may cause more frequent web breaks and press shutdowns. The printing of these more troublesome products could require the press operators to enter a cabin enclosure more often than required at Meredith/Burda, thereby increasing their potential for exposure to solvent vapors. Press operating data supporting this reasoning, as discussed in Chapter 3, were obtained during the two plant tests and general information provided by industry on typical operations. Therefore, a cabin enclosure design may not be a suitable fugitive vapor capture system for some facilites.

Analysis of the Meredith/Burda capture system and pressroom design shows that some design improvements could be incorporated to facilitate compliance with OSHA regulations. First of all, the pressroom ambient solvent vapor concentration level could be substantially decreased through modification of the pressroom air handling system.[49] The SLA exhaust from the air handling system for the product cutting/folding areas could be redirected to the carbon adsorption system instead of being circulated through the pressroom. Infiltration of solvent vapors to the newest pressroom from other areas of the printing plant could be minimized by keeping the pressroom doors closed when possible and by decreasing the ambient solvent vapor concentration in the adjacent hallways and rooms through better ventilation. Secondly, at the time of a press shutdown, the solvent vapor concentration inside the cabin enclosure could be decreased faster and more uniformly through modification of several of the cabin design features.[50] An individual cabin provides an enclosure for the printing press units in common with the product cutting/folding area. Propagation of fugitive solvent vapors from the printing press units to the cutting/folding air handling system could be eliminated through installation of a separating wall inside the cabin enclosure. The solvent vapor concentration profile and stagnant vapor zones inside the enclosure could be minimized or eliminated by correcting the maldistribution of air flow through the cabin. The ends and room side of the cabin are totally closed, while the wall side is essentially open on each enclosure. Completion of the enclosure on the wall side and installation of more floor inlet nozzles would redirect entering air through the cabin floor and should help to correct the maldistribution problem. Finally, an increase in the air flow rate through the cabin, from the measured 11,900 nm^3/hr (7,000 SCFM) to the design 17,000 nm^3/hr (10,000 SCFM), would help minimize the time required to decrease the cabin solvent vapor concentration level to below the OSHA standard limit, at the time of a press shutdown. Theoretical calculations presented in Appendix C show that the increased air flow rate would cause a decrease of less than 0.5 percent in the carbon adsorber efficiency.

A third type system which captures all the pressroom air was demonstrated at the Standard Gravure plant. This system is similar to what the potential Texas Color capture system would be with the fugitive ventilation air directed to the control device. In addition, ventilation air from the cutting, folding, and product storage areas are captured at this plant and sent to a carbon adsorption system. Tests were not conducted at this plant because the amount of capture air required with this design was much greater than for the Meredith/Burda or the Texas Color potential capture system designs.

The Triangle Publications plant also attempted to capture all the pressroom air.[51,52] However, this plant ceased operations in July 1978; detailed data on the capture system was not obtained.

4.2.2 Capture Efficiencies

The actual capture efficiency is difficult to measure. There are several routes through which solvent can leave the presses, as previously described. The adsorber efficiencies can be determined by analyzing the vapor concentrations of both the inlet and outlet SLA streams of the adsorber bed during the adsorption cycle. The overall emission reduction efficiency is equal to the capture efficiency times the adsorber efficiency. Therefore, the average operating capture efficiency can be calculated by dividing the overall control efficiency by the measured average adsorber efficiency.

Demonstrated capture efficiencies were calculated using test data from two plants. The results of these calculations are presented in Appendix C. The newest Meredith/Burda facilities with the fugitive vapor cabin enclosure system captures 94 to 97 percent of the total solvent volume used at the presses. Solvent retained in the printed product and uncaptured fugitive vapors account for the remaining 3 to 6 percent. The Texas Color Printers facilities achieved capture efficiencies of about 85 to 89 percent by capturing only the dryer exhausts.

Additional calculations presented in Appendix C show that the Texas Color capture efficiency could be potentially increased by directing their fugitive ventilation vents to the adsorption system rather than to the atmosphere. Solvent vapor analyses of the fugitive emissions discharged from the Texas Color pressroom showed that the ventilation system captured about eight percent of the total solvent volume used at the presses. Calculations adding these fugitive vapors to the dryer exhausts show potential capture efficiencies of 93 to 97 percent. The remaining three to seven percent represents solvent retained in the printed product.

4.2.3 Best Capture Systems

There is some uncertainty as to what is the best demonstrated capture system. The Meredith/Burda cabin enclosures probably represent the most effective vapor capture system, requiring the least amount of SLA handling to capture essentially all fugitive vapors from the presses. However, this type enclosure may require some modifications to improve the air flow patterns within the enclosure and reduce vapor concentrations below OSHA limitations. The inks and solvent used at Meredith/Burda contain a single toluene component. Other plants, including Texas Color and Standard Gravure, use the naphtha-based mixed solvent. The mixed solvent contains components which are more volatile than toluene. There could be a tendency for larger amounts of fugitive vapors with the mixed solvent. However, a well designed capture system should be just as efficient with either solvent. This was demonstrated when the capture efficiencies at Texas Color were calculated to be potentially just as high as at Meredith/ Burda. In addition, the use of naptha-based mixed solvents would pose fewer problems in complying with OSHA regulations since the standards for some of the solvent components allow higher vapor concentrations in the air (see Chapter 7). Therefore, the highest capture efficiencies should be achievable by employing partial enclosure systems with the use of either type solvent. On the other hand, printing of some products handled by this industry might cause more press down time than other products, and thus a cabin enclosure design may not be a suitable capture system for some facilities.

Other capture designs may gather a high percentage of the fugitive vapors, but larger amounts of SLA would be handled, lowering the cost and energy effectiveness. All of the pressroom air could be captured along with the dryer exhausts and SLA from the cutting, folding, and product storage areas, such as practiced at the Standard Gravure plant.

The amount of air required to capture the fugitive vapors depends upon the design and installed placement of the capture system. Less amounts of air may be required to be captured with designs installed close enough to the press areas to pick up the highest concentrations of solvent laden air. An enclosed pressroom with multiple fugitive vapor pickup vents, located as close as practical and perhaps with "swing away" features for maintenance, combined with regulated floor sweep vents may be a very efficient capture system alternative. However, the ultimate efficiency of any capture system is limited by the amount of solvent retained in the printed product.

The variations in press widths, press operating speeds, and number of printing units per press can significantly affect the amount of air handled by the capture system. Operating conditions such as a narrow web being printed on a wide press, decreased ink coverage, and technological advancements allowing press speeds of over 10.2 m/s (2,000 fpm) could cause decreased capture efficiency and excessive dryer exhaust SLA dilution. These effects were shown during the two plant tests while printing both narrow and full width webs with several different products and ink coverages.

Excess air dilution could be minimized by designing flexibility into the solvent vapor capture system. A VOC vapor monitor could be installed in the dryer exhausts streams to control the amount of internal air recirculation; this would maximize the VOC vapor concentration in the SLA stream treated by the control device. Adjustable width openings for the dryer inlets and outlets could be designed to help minimize the amount of dilution air drawn into the dryer. These adjustments could be made when the printing cylinders are changed between job runs. More thorough dryer designs will need to be utilized to handle the higher press speeds. In addition, fugitive vapor capture-air systems incorporating valve-diverting or turndown mechanisms could be installed for periods of low production and press shutdowns.

In summary, the facilities at both tested plant sites demonstrated that at least a 90 percent average capture efficiency can be expected when fugitive solvent vapors are captured along with the dryer exhausts from new presses. This conservative average efficiency allows for printing of products that retain larger amounts of solvent or that cause more fluctuations in the printing operations than were experienced during the two short-term plant tests. If only dryer exhausts are directed to the control device, then the average capture efficiency can be expected to be only about 85 percent, as demonstrated during tests at Texas Color. Older facilities handling only the dryer exhausts can be expected to achieve an average capture efficiency of about 84 percent. This lowest capture efficiency reflects an estimate of slightly more fugitive solvent vapor losses from the more exposed areas of older press designs.

4.3 FIXED-BED CARBON ADSORPTION/SOLVENT RECOVERY

4.3.1 General Description

Fixed-bed carbon adsorption is currently the most widely used method for the control of solvent vapor emissions in this industry. These systems involve the use of at least two adsorption vessels. At any one time, adsorption is occurring in one bed while desorption or regeneration is occurring in another.

The adsorption process is a physical phenomenon that involves the removal of solvent vapor from an air stream. The solvent vapor is concentrated on the surface area of the pores of activated carbon. The adsorbent used in this instance is a bed of small carbon pellets. Activated carbon is a highly porous solid employing Van der Waals' forces to adhere the solvent molecules to the pore surface.

When a solvent vapor mixture is being adsorbed, the solvent vapor molecules of lower molecular weights are gradually displaced by the heavier, less volatile molecules. As the adsorption process continues, the carbon becomes saturated with the lower molecular weight components, and starts desorbing them. In time, the carbon will become saturated with all the solvent components, and the adsorber outlet vapor concentrations will be the same as the inlet.

Initially, the adsorption process is rapid and complete. During the course of the adsorption cycle, the outlet solvent vapor concentration remains relatively constant until breakthrough occurs. Once this significant saturation has occurred, the outlet solvent vapor concentration rapidly increases. The percentage of the inlet solvent concentration measured at the outlet is defined as the percent breakthrough. Before an unacceptable level of breakthrough is reached, the air flow is transferred to a freshly regenerated bed, and the saturated bed is regenerated.

Regeneration is usually accomplished by backflushing the carbon bed with low-pressure steam. This operation is generally called the stripping cycle. The steam heats the bed and provides the heat of desorption of the solvent. The steam also functions as a diluent, lowering the partial pressure of the solvent. The solvent is then recovered by condensing the solvent-laden steam, and separating the liquid mixture by decanting. Figures 4-3 and 4-4 illustrate a typical carbon adsorption solvent recovery process in the adsorption and desorption modes.

4.3.2 Equipment Design

The captured solvent laden air (SLA) is drawn from the printing presses and through a filter by several fans. A cooler is also installed in some designs. The purpose of the cooler is discussed later. There is usually one operating filter with at least one spare. The filters usually consist of a single, thin fiberglass curtain extended the full width from the ceiling to the floor inside a large housing. The housing is sized to greatly reduce the air velocity and allow the heavier entrained dirt and paper dust particles to settle out. The smaller particles are caught by the filter curtain. The pressure drop across the filter must be monitored. The SLA is switched to the spare filter at a preset value, or when the pressure drop begins to affect the operating capacity of the fans. The large fans are normally of centrifugal design with at least one spare. The design of the fans and their operating costs are directly influenced by the pressure drop across the filters and the carbon adsorption beds. The resulting pre-conditioned air is then directed to the adsorption vessels.

The operating differential pressure of typical centrifugal fans is limited to about a maximum 500 mm (20 inches) of water pressure. Other SLA moving devices, such as blowers and compressors, could be used to achieve higher pressures, but the capital costs of these more complex air-movers are much higher compared to centrifugal fans. The discharge pressure of most fans in existing carbon adsorption systems ranges from about 150 to 250 mm (6-10 inches) of water pressure.

A fixed-bed carbon adsorption system requires at least two adsorption vessels. Most small plants have at least three, while some larger plants have ten or more vessels. In some cases, the fixed carbon beds are cone or dome shaped to allow more surface area for gas contact at

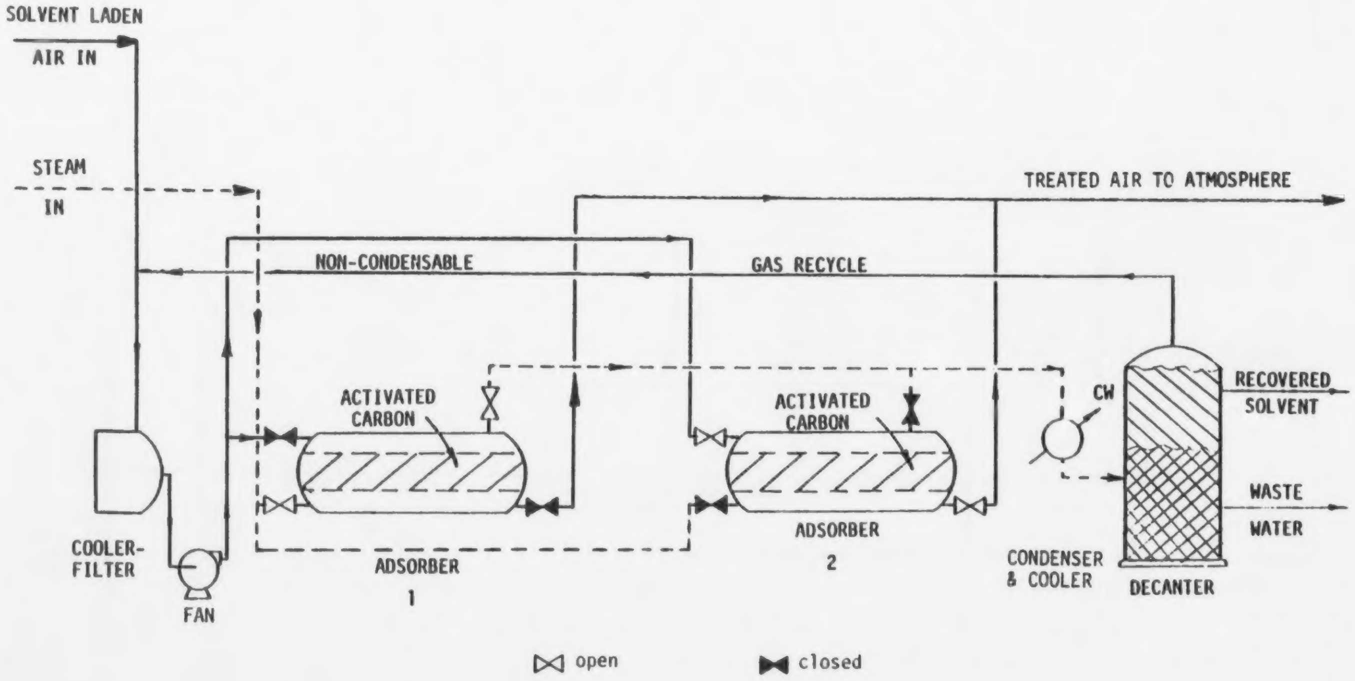
SOLVENT LADEN
AIR IN
STEAM
IN
NON-CONDENSABLE
GAS RECYCLE
TREATED AIR TO ATMOSPHERE
ACTIVATED
CARBON
ACTIVATED
CARBON
CW
RECOVERED
SOLVENT
WASTE
WATER
COOLER-
FILTER
FAN
ADSORBER
1
ADSORBER
2
CONDENSER
& COOLER
DECANTER
open
closed

Figure 4-3. Flow diagram of typical solvent recovery process (Adsorber 1 regenerating).

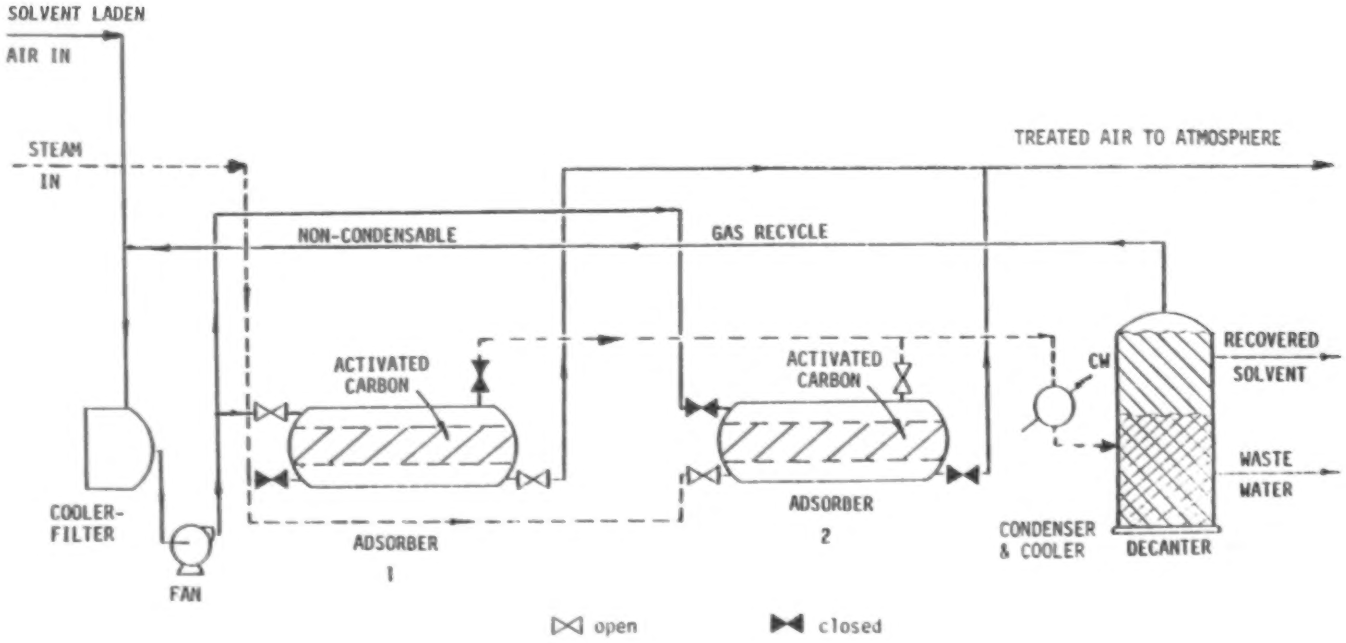
SOLVENT LADEN
AIR IN
STEAM
IN
TREATED AIR TO ATMOSPHERE
NON-CONDENSABLE
GAS RECYCLE
ACTIVATED CARBON
ACTIVATED CARBON
CW
RECOVERED
SOLVENT
WASTE
WATER
COOLER-FILTER
FAN
ADSORBER
1
ADSORBER
2
CONDENSER & COOLER
DECANTER
⋈ open
⧓ closed

Figure 4-4. Flow diagram of typical solvent recovery process (Adsorber 2 regenerating).

higher gas flow rates. The conventional carbon adsorption vessel is limited to a gas flow rate of about 65,000 m^3/hr (38,000 CFM). This accounts for the large number of adsorption vessels required in some of the larger printing plants. A vertical multi-bed adsorption vessel employing the same principles as the once-through flat bed design, previously described, makes more efficient use of limited space. In this design, the carbon beds are situated above one another and the air flow is directed through an annular header so that adsorption takes place simultaneously among all the beds in the vessel.[53,54] This design permits at least twice the solvent laden air (SLA) capacity per vessel than conventional vessels allow, without sacrificing any efficiency.

The total operating cycle for carbon adsorption systems is comprised of several steps. The adsorption step time typically ranges from 1 to 8 hours. The duration of the adsorption step is sometimes regulated only by a timer. However, optimum performance can be obtained by installing a gas analyzer to monitor the adsorber outlet, with a timer as backup. The gas analyzer initiates regeneration when the outlet solvent vapor concentration reaches a preset value. Such instrumentation control then allows the actual pressroom activity to determine the time span of the adsorption cycle. The regeneration steps begin with desorption, or steam stripping. This step is usually controlled by a timer. Times range from 0.5 to 2 hours, depending on boiler capacity and maximum design steam velocities through the carbon bed. Finally, 15 to 20 minute long drying or cooling step is usually included to minimize premature breakthrough once the bed is returned to the adsorption step.

The adsorption system efficiency depends upon the correct, appropriate sizing of the carbon bed. The following information is needed to properly size a system:

- Solvent laden air (SLA) flow rate,
- Maximum inlet vapor concentration,
- Maximum desired outlet vapor concentration, or desired efficiency,
- Allowable pressure drop,

- Operating conditions, such as temperature, pressure, and humidity,
- Chemical nature and physical properties of all vapor components,
- Steam to solvent ratio,
- Space limitations,
- Available utilities, and
- Desired instrumentation controls.

The type and size of the carbon packing affects the overall bed size. Activated carbon is a product of organic matter (e.g. peat, wood, brown coal, coconut shells), which is produced in numerous special grades. The typical granular carbon particles range in size from 1 to 5 mm, or 4 to 10 mesh equivalent. The bulk packing density ranges in size from 380 to 480 Kg/m^3 (24-30 lb/ft^3).[55,56] The selected carbon grade must have suitable affinity for the solvent vapor components. A summary of approximate adsorption capacities for selected rotogravure solvent components is shown in Table 4-2.

TABLE 4-2. APPROXIMATE CARBON ADSORPTION CAPACITY FOR VARIOUS SOLVENTS, KG SOLVENT/KG CARBON (LB SOLVENT/LB CARBON)[57]

Heptane	0.06
Hexane	0.06
Toluene	0.07
VM&P Naphtha	0.07
Xylene	0.10

The capacity of the carbon to adsorb solvent vapors is also a function of the pressure and temperature. The adsorption capacity of carbon increases significantly as temperature decreases. Gas coolers are frequently used to keep the solvent laden air at or below 41°C (105°F) to insure good adsorption efficiency. The operating pressure has only a small influence on the efficiency, providing that the pressure is near atmospheric.

The capacity of the selected carbon and the design cycle time serve as the basis for sizing the bed. The total amount of carbon needed is then determined by the SLA flow rate, inlet vapor concentration, and desired efficiency. An efficient and economical adsorption system requires a stable gas velocity with a uniform solvent vapor concentration. The gas velocity determines the residence time of the solvent vapor in the bed. Typical design superficial velocities range from 21-30 m/min (70-100 ft/min). The SLA inlet hydrocarbon vapor concentrations from publication rotogravure presses range from 1 to 10 g/m^3 (300-2600 ppm V/V).[58,59,60] Many existing adsorption systems were originally designed for only 90 to 95 percent "bed efficiency". However, newer systems can be designed for 97 to almost 99 percent efficiency.

The highest adsorber efficiencies can be designed with the highest inlet SLA vapor concentrations. The press unit dryer exhausts can be recycled to increase the solvent vapor concentrations. When dryer exhaust recycling is used, however, the vapor concentration must be regulated to insure operation sufficiently below the lower explosive limit (LEL). Gas analyzers can be installed for maximizing the dryer exhaust vapor concentration to the allowable safe level (see section 3.2).

The design thickness of the carbon bed is a function of the allowable pressure drop, as well as the inlet vapor concentration. The pressure drop across the adsorber is directly proportional to the SLA flow rate and the thickness of the carbon bed. The packing density also affects pressure drop. A gross oversizing of the carbon bed thickness would create an excessively high pressure drop. The resulting pressure drop directly affects the power consumption and the electrical costs for operating the SLA fans. A design compromise is usually reached between thick beds for higher efficiency, and thin beds for lower electrical operating costs. Frequently, the bed thickness is determined by considering the maximum inlet vapor concentration excursion expected. Operating costs will be higher for a more efficient adsorber, which is designed to handle the cases where peak vapor concentrations are considerably higher than average values. Most of the adsorption vessels presently installed in this industry contain beds of activated carbon from 0.5 to 1.2 meters (20-50 inches) thick.[61,62] A combination of this bed thickness range with the 500 mm (20 inches) of water maximum pressure available with centrifugal fans shows that the pressure drop across the carbon bed must be less than 400 to 1,000 mm of water per meter (5-12 inches of H_2O/ft) of bed depth. The appropriate carbon particle size must be selected based on the design superficial air velocity through the bed to limit the pressure drop to below the allowable level. A wide range of granular activated carbons is commercially available to satisfy these pressure drop requirements.[63]

Regeneration expenses, which are essentially the steam costs, are also affected by the solvent vapor content of the exhaust gas. When a carbon bed is regenerated, approximately one-third of the total steam consumption is used to heat the bed up to regeneration temperature. This initial steam flow does only a small fraction of the total stripping. A system which requires frequent regeneration usually has poor steam utilization efficiency. Consequently, carbon beds are designed to be just thick enough to handle the solvent concentration without too frequent regeneration, yet thin enough to limit energy consumption from the fans.

Another parameter which affects the design efficiency and operating cost of the fixed bed system is the breakthrough point. A very low breakthrough point will yield a high adsorption removal efficiency although the adsorption capacity (per cycle) will decrease. The steam consumption per unit of recovered solvent will increase accordingly. This increased steam requirement will raise fuel costs. A higher breakthrough point will, on the other hand, reduce fuel consumption by decreasing the frequency of steam regeneration. Some adsorption systems have been designed with gas analyzers to monitor and control the adsorber outlet hydrocarbon vapor concentrations. Adsorption systems at three publication rotogravure printing facilities are regenerated at breakthrough points as low as 15 and to 30 ppm (V/V).[64,65,66,67]

The regeneration step of the adsorber cycle is designed to desorb most of the retained solvent, and recondition the carbon bed. Low pressure saturated steam has been the only stripping method used to regenerate the carbon beds in this industry. First, the SLA flow through the bed is stopped. Then, steam at 1.8 to 3.5 Kg/cm^2 (25-50 psig) is admitted through the bed, usually in a counter-current direction to the SLA flow. The steam flow rates depend on the adsorber size and boiler capacity. Typical design flow rates range from 3600 to 6800 Kg/hr (8,000-15,000 lbs/hr). The design steam to recovered solvent ratio for older, existing systems range from about 4.0 to over 6.0 on a weight per weight basis.[68,69,70] However, newer designs promise lower ratios of from less than 4.0 down to 1.8.[71,72,73,74]

The steam and solvent vapor mixture is directed out of the bed and condensed. The condenser and an associated cooler are sized according to the steam flow rate. Tempered water at about 24°C (75°F), which is usually a mixture of chilled water and cooling tower water, is used as the coolant.

The subcooled, condensed two phase solvent/water mixture then flows down to a decanter. The decanter is simply a liquid-liquid gravity separator. Fortunately for this industry, the solvents used are almost immiscible with water and can be readily separated from the steam condensate. The less dense solvent flows upwards while the water settles to the bottom of the decanter. The decanter capacity, usually several hundred gallons or more, is sized according to the condensate flow rate. The decanter is sometimes a vertical vessel; however, horizontal designs are employed where more residence time is required for the solvent/water separation. The decanted solvent does not normally require any additional treatment. This recovered solvent can be recycled to the printing presses for solvent addition or sold as a by-product.

Dissolved solvent in the condensate from the decanter is a source of solvent loss from carbon adsorption systems. The solvent content depends on the specific solubility of the individual solvent components. In addition, the solubility of most organic liquids in water increases with temperature. Analyses of condensate samples at two plants showed solvent concentrations ranging from 130 to 2,000 ppm.[75,76] This small amount of solvent loss typically represents less than one percent of the total solvent used at the printing presses. However, this potential source of water pollution and solvent loss can be virtually eliminated by stripping the condensate.

Hot-air stripping of the condensate is one demonstrated method for removal of the solvent content.[77,78] Ambient air is drawn up through a steam heated packed column by the SLA fans. The solvent laden condensate is directed down through the packing, counter-current to the air flow. The SLA from this stripper is then directed into the adsorber inlet header for recovery. This process reduces the condensate solvent concentration to less than 3 ppm.[79] The stripped steam condensate can then be recycled as hot boiler-feed water or reused as essentially solvent-free cooling tower water makeup. Other methods for handling of this waste water are discussed in Chapter 7.

Vacuum regeneration is an alternative method for stripping the carbon bed.[80] The total adsorber cycle is similar to that for steam regeneration, except that steam is not mixed with the re-evaporated solvent during the desorption step. In this case, the carbon bed vessels are usually constructed with an external jacket. During the regeneration cycle, steam is admitted through the vessel jackets to heat the carbon bed indirectly. The carbon is heated to approximately 175° to 225°F, or at least 50° to 60°F above the adsoprtion temperature. A vacuum is then applied to the hot carbon bed to remove the solvent. The solvent vapors are then condensed and cooled without any further required treatment steps for water separation. With the condenser on the suction side of the vacuum pump, the system constitutes a vacuum distillation facility. This condensing design is relatively expensive, requiring a large refrigerated or chilled water condenser. A less expensive design alternative is to condense on the discharge (pressure) side of the vacuum pump. The capital cost of vacuum desorption systems are comparable to steam regeneration systems; however, the operating costs tend to be higher with the vacuum system.[81] In general, vacuum desoprtion designs would only be used if there are handling or treatment problems for disposal or recycling of the condensate waste water from steam regeneration systems.

There are several other carbon adsorption system design features which must be considered. The materials of construction and valve designs can greatly affect the long term performance of adsorption systems. Design decisions must be made between lower cost valves and carbon steel construction, versus better valve design and corrosion resistant alloys. Most new adsorbers are constructed of carbon steel shells with titanium bed supports. The condenser and some condensate systems are made of stainless steel. The vents from the condenser and decanter are usually directed back into the adsorber inlet header. In addition, a decision must be made on the method to dry and/or cool the carbon bed at the end of the regeneration cycle. Some designs use the inlet solvent laden air while the adsorber outlet air can also be used if the pressure drop is not excessive.

4.3.3 Performance

The performance of a carbon adsorption system can be expressed in terms of emission reduction and relative economy. When new and operating within design conditions, many of these fixed bed systems will reduce the inlet SLA vapor concentration by 99 percent or more. Discrepancies between the design and actual operating bed efficiencies can be the result of changing inlet SLA vapor concentrations, carbon attrition, deactivation, bed blockages, corrosion and valve leakages. However, several carbon adsorption systems installed in this industry, provide evidence that the carbon bed still maintains the design "activity" for more than five years.[82,83,84] The relative economy is a function of electrical power usage for the SLA fans, and steam usage for bed regeneration.

Some of the larger carbon particles are reduced to fine particles (fines) because of mechanical abrasion. Thermal degradation weakens the carbon binder and accelerates the formation of carbon fines. These fines increase the pressure drop across the carbon bed and reduce the potential air flow rate. Periodic maintenance can minimize these adverse effects. The carbon fines can be withdrawn from the bed by filtering. New makeup carbon can be added, as needed, to replace the carbon fines.

High molecular weight by-products entrained dirt, and residues can decrease the carbon's adsorption/desorption ability. A good SLA filtering system should minimize these problems. In some services, the carbon can gradually become less effective after several years; replacement of the carbon bed is generally required after about five years. The solvent molecules with the lower molecular weights are more loosely adsorbed, and therefore, are the first to be desorbed. A small portion of even the easiest to remove solvents are not desorbed from the carbon. The energy and time required to remove the last traces of solvent does not justify the additional capacity regained. For this reason the relevent adsorption capacity of a carbon bed is actually the working capacity rather than the total capacity. The working capacity of a carbon bed is essentially the amount of solvent adsorbed at the specified breakthrough percent. The small amount of retained solvent, which is the difference between the total and working capacities, is called the heel. With some solvent mixtures, this heel can be an accumulation of high molecular weight compounds present in trace quantities. If the compounds present in this heel are reactive, then partial blockage of the carbon pores could take place over a period of time from the formation of high molecular weight reaction products. However, these "bed blockages" have not occurred with existing adsorption systems and solvent blends used in the publication rotogravure printing industry.

Other operational problems associated with the fixed bed carbon adsorption systems can be corrosion and valve leakage. Major corrosion problems are generally eliminated when stainless steel condensers and piping are used. Titanium alloys have been successfully used as internal bed supports in many cases. Carbon steel is generally used for the remainder of the equipment. Valve leakage, which can also account for a gradual loss of emission reduction efficiency, occurs when corrosion and wear act on the valve seats. Easily replaceable valve seals and seats minimize this problem. In addition, this problem can be virtually eliminated with modern "tight-shutoff" valve designs, and corrosion resistant construction.[85]

The typical instrumentation for a fixed-bed carbon system usually includes outlet hydrocarbon analyzers, which are used to initiate regeneration after breakthrough is detected. A timer override is usually coupled with hydrocarbon analyzers. The steaming cycles are usually controlled by either separate timers or steam totalizers for each bed. In some cases the adsorption-desorption cycle is totally controlled by timers. The best compromise for sustained high efficiency operation, and minimum steam consumption is obtained by using hydrocarbon analyzers. Hydrocarbon breakthrough analyzers initiate regeneration only when it is needed.

Another technique which enhances overall emission reduction is a cooling/drying cycle. High temperatures and wet conditions impair the adsorption ability of a carbon system. The carbon beds can be cooled and further stripped of hydrocarbons at the end of each regeneration cycle. Filtered ambient air or treated exhaust air is forced into the freshly regenerated bed to disengage any trapped steam and solvent condensate. This effluent is discharged into the condenser or is routed back into the inlet manifold to the adsorbers. The non-condensable gases from the condenser and decanter are also routed back into the inlet manifold of the adsorbers.

Actual adsorber operating efficiencies were measured at the Meredith/Burda plant (M/B) and the Texas Color Printers plant (T/C).[86,87] The summarized data presented in Appendix C shows that the M/B adsorber efficiency ranged from 97 to 98 percent; while the T/C adsorber efficiency ranged from 88 to 97 percent. The vapor concentration levels of the inlet solvent laden air (SLA), as well as the outlet, appear to be the main reasons for the less efficient T/C adsorbers. Appendix C shows that the maximum vapor concentrations at T/C were about 40 percent lower than at M/B. The M/B press unit dryers have gas analyzers for maximizing the allowable exhaust vapor concentrations; the T/C dryers do not have such analyzers. The allowable vapor concentration at T/C must be lower because the lower explosive limit (LEL) of the solvent-blend vapors is 8,000 -10,000 PPM, versus 12,700 PPM for toluene. However, an increase in the T/C vapor concentration to the 1,900 PPM maximum detected M/B inlet level would result at only 21 - 24 percent of the LEL. The M/B dryer exhaust's level was calculated to be about 2,300 PPM, as shown in Appendix C. This represents a level of almost 19 percent of the toluene LEL and about 26 percent of the naphtha solvent LEL. Both these levels should be well below insurance requirements. In addition, information from the Alco-Gravure and Standard Gravure plants show that adsorbers can be designed to control the outlet concentration to less than 15 PPM.[88,89,90] Thus, the installation of dryer exhaust analyzers and adsorber outlet analyzers with better adsorber design could increase the T/C adsorber efficiency to the level of M/B.

The instantaneous adsorber efficiency fluctuates with changes in the inlet SLA vapor concentrations. The adsorbers are designed to handle the maximum expected vapor concentrations (1600 to 2,000 ppm) at the matched capacity of the SLA fans. The amount of solvent vapors is greatly reduced during press shutdowns. The adsorber outlet concentration will remain unchanged; however, the adsorber efficiency will decrease during press shutdowns because of the dilute inlet SLA concentrations. Therefore, some sort of time averaged adsorber efficiency should be used.

The duration of the combined press operating modes with the resulting adsorber inlet vapor concentrations are presented in Appendix C. Operating mode times at both plants were practically identical. Both presses were printing about 60 percent of the time, while only one was down about 33 percent of the time. Both presses were down about 7 percent of the time. This data can serve as a basis for determining adsorber efficiency variation.

A time weighted average adsorber efficiency of 97.9 percent was calculated, as shown in Appendix C. This calculation is based on the combined shutdown/running operations for two presses. The calculations show that the instantaneous efficiency can vary from the design maximum of 98.8 percent, down to 93.3 percent. Therefore, these results show that a realistic average 97 percent adsorber efficiency can be assumed for modern, well instrumented fixed-bed adsorption systems in this industry.

High inlet SLA concentrations decrease the adsorption cycle time but improve steam efficiency. The steam efficiency is expressed as the ratio of steam used to solvent recovered. Calculations presented in Appendix C show that operating ratios at M/B range from 3.0 to 3.7 pounds of steam per pound of recovered solvent. Instrumentation was not available to determine the operating ratio at T/C. However, T/C plant personnel mentioned that a typical ratio of about 4.5 is expected.[91] If the SLA inlet concentration becomes very dilute, a small increase in adsorption cycle time will occur but at the expense of very poor steam efficiency. The best overall performance is obtained when the SLA inlet concentration remains high. Both steam and emission reduction efficiency will be best at high SLA inlet concentrations. Therefore, a well designed and properly operated solvent vapor capture system is essential to maintaining high control efficiencies.

In summary, the long-term average performance of fixed-bed carbon adsorption/solvent recovery control systems is expected to be slightly different from the performance results of the two short-term plant tests. Modern carbon adsorbers can be expected to achieve a long-term average solvent vapor reduction efficiency of about 95 percent. Short-term efficiencies of the best demonstrated adsorbers may be higher at times, but this average efficiency accounts for wide fluctuations of the SLA vapor concentrations at the inlet to the adsorber. In comparison, older adsorber systems were designed to perform at about only a 90 percent average efficiency. The long-term average steam to recovered solvent ratio is expected to be about four to one, on a weight basis. However, newer design specifications by some equipment manufacturers indicate that this may be a conservatively high ratio.

4.4 FLUIDIZED BED CARBON ADSORPTION/SOLVENT RECOVERY

Fluidized-bed carbon adsorption systems are used to recover solvents in several publication rotogravure plants in Japan. This control system, which is presently marketed in the U.S. by Union Carbide Corporation, is being installed on a domestic plant. The system is called the PURASIV HR process.[92] There is no domestic operating data available as yet, but the system looks very promising.

Fluidized-bed carbon adsorption is a continuous process. Adsorption and desorption occur simultaneously in a single vertical vessel, which resembles a sieve tray distillation column. The adsorbant used is beaded activated carbon spheres which flow countercurrent to the exhaust gas. As the solvent-laden exhaust gas flows upward, it contacts the activated carbon in the adsorption section and the solvent is removed. The clean gas exits through the top of the vessel while the carbon beads, now containing the solvent, continue down to the desorption zone. In the desorption zone, the carbon is indirectly preheated with steam. The solvent is then stripped from the carbon through direct contact with steam. The regenerated carbon is then carried back to the top of the vessel by a carrier gas and is ready to repeat the process. The steam-solvent vapor exits through the desorption section and is condensed. The solvent can be removed by decanting or distillation.

One advantage of this system is that it is not limited to steam as a stripping medium. Because the stripping medium can be recycled, pure nitrogen can be used economically in its place. The advantage this replacement offers is a large reduction in condenser size. It also eliminates the condensate clean-up problems present in the steam system. The use of steam can be eliminated completely by substituting an indirect hot fluid heating system to preheat the solvent-laden carbon. With this system, a preheat temperature of about 200-260°C (400-500°F) can be achieved as opposed to about 100°C (212°F) with steam. This increase in temperature decreases the amount of nitrogen required to strip the solvent, thus reducing stripping gas costs. A decrease in the amount of stripping gas further reduces the size of the condenser required for solvent recovery. The volume of carbon is also decreased. For these reasons, the substitution of an indirect hot fluid preheating system with nitrogen gas stripping is an economical way to eliminate steam from a system where no extra steam capacity is available.

The fluidized-bed process offers a lower energy consumption (for a given flow rate of SLA) than a fixed-bed system. This advantage is partially offset by the fact that the system air flow rate must remain constant; and therefore, significant turndown does not reduce operating costs. The fluidized-bed system is a new process in the United States and previous operating experience is minimal. The capital investment is also higher than any other control method investigated.

4.5 SOLVENT DESTRUCTION

Solvent destruction (i.e. oxidation) is a widely used method of air pollution control for VOC and other organic vapor emissions. This control technique destroys the organic vapors by thermal or catalytic oxidation to carbon dioxide (CO_2) and water (H_2O), along with carbon monoxide (CO) and nitrogen oxides (NO_x) and other reaction products formed from non-organic components (e.g. halogenated organics). At present, there are no solvent destruction control devices being used on publication rotogravure facilities in this country.

Most thermal oxidation systems rely on large amounts of supplemental fuel to sustain combustion temperatures. Typical oxidation temperatures range from about 450°C to 980°C (850°-1800°F). Consequently, if a large quantity of thermal energy is not needed at a plant site, the system becomes very costly to operate. Although primary heat recovery will reduce the fuel requirements by preheating the SLA feed gas, the fuel requirements can be still quite substantial. Additional energy savings would result if secondary heat exchangers were used to preheat the dryer inlet air on the printing press units. Existing publication rotogravure printing press dryers are not designed to accommodate this feature. Although it is probably possible to make use of this secondary heat, it has not been demonstrated. The printing press dryers are designed to use steam as an energy source. The steam enters a heat exchanger which heats the dryer circulation air. If hot exhaust gas from a thermal oxidation device were used in place of steam, the dryer design would require modification to increase the size and change the design of this secondary heat exchanger.

Catalytic oxidation offers reduced fuel requirements, but still requires large amounts of fuel to heat-up the SLA feed gas unless elaborate primary heat recovery is employed. The use of a catalyst permits lower oxidation reaction temperatures, and therefore, requires about 50 percent less fuel than for thermal oxidation. The catalyst ignition temperatures for most of the VOC components of the SLA from rotogravure printing facilities range from about 300°C to 315°C (575° - 600°F).[93] The exhaust gas temperature must be controlled between 480°C and about 650°C (900° - 1,200°F) to ensure adequate VOC destruction without deactivating the catalyst by overheating.[94] Secondary heat recovery could also be used with catalytic oxidation devices, although it would be less effective since the exhaust gas temperature is much lower than for thermal oxidation devices.

Another approach, introduced by REECO Inc., is called the RE-THERM system.[95] This system thermally oxidizes dilute hydrocarbon vapor streams by passing the stream through regenerative combustion beds. Thermal recovery efficiencies of 85-90 percent can be achieved.

The RE-THERM system utilizes a vertical, cylindrical combustion chamber surrounded by a series of packed, stoneware beds. Top and front views of a five-bed system are illustrated in Figures 4-5 and 4-6, respectively. The pressroom exhaust enters a feed header, gets preheated through a hot bed, and passes through the high temperature 760°C (1400°F) combustion chamber. The hot combustion gases pass through a different stoneware bed transferring the heat of combustion to that bed. Inlet and exhaust valves on each bed control the gas flow as the bed is depleted or saturated with heat. Each bed goes through this depletion/saturation cycle every few minutes.

An energy savings and fuel cost savings can result providing that the printing plant can use all of the waste heat generated.[96] The RE-THERM system is self-sustaining, requiring little or no fuel, if the inlet waste gas has a hydrocarbon content of at least 4 to 5 percent of the lower explosive limit (LEL). The hydrocarbon vapor centent of typical SLA streams from rotogravure presses usually corresponds to at

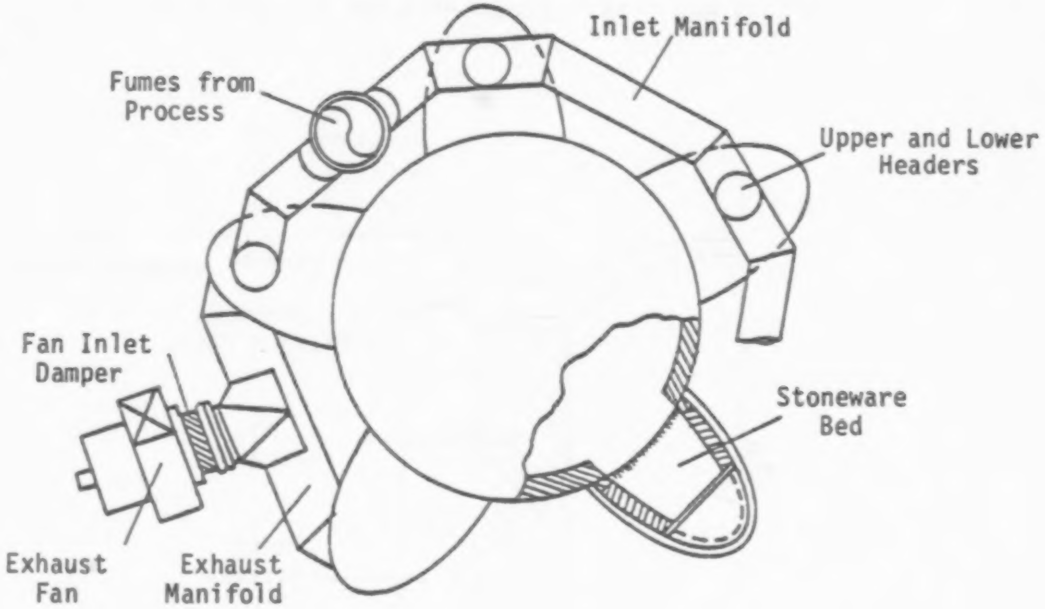
Fumes from Process
Inlet Manifold
Upper and Lower Headers
Fan Inlet Damper
Stoneware Bed
Exhaust Fan
Exhaust Manifold

Figure 4-5. Top view of REECO RE-THERM system.

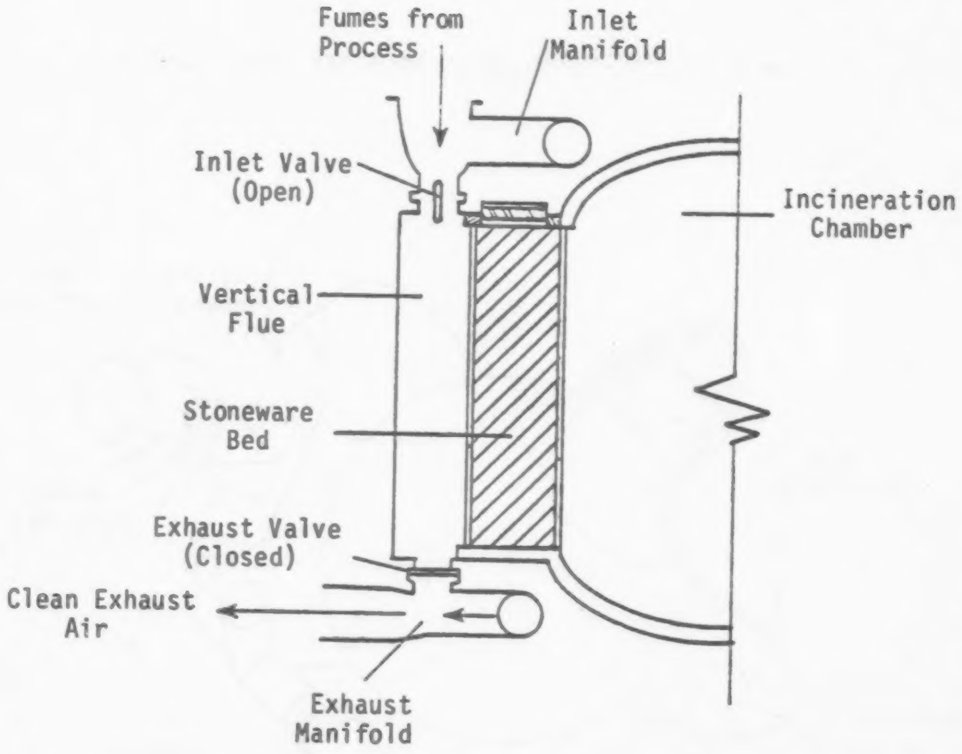
Fumes from Process
Inlet Manifold
Inlet Valve (Open)
Incineration Chamber
Vertical Flue
Stoneware Bed
Exhaust Valve (Closed)
Clean Exhaust Air
Exhaust Manifold

Figure 4-6. Front view of REECO RE-THERM system.

least 10 percent of the LEL. The regenerative combustion system is the only attractive solvent destruction device for this industry. This oxidation process may provide fuel cost savings if the hot exhaust gas can be used for pressroom heating and to generate the process steam required in the printing press unit dryers. However, solvent supplies are closely related to gasoline and other fuel supplies, which will become less available and more expensive in the future. Therefore, a good solvent recovery system is probably the better choice for this industry.

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5. MODIFICATION AND RECONSTRUCTION

5.1 GENERAL

In the publication rotogravure printing industry, each printing plant is considered to be a stationary source, while each production press is considered to be a separate facility. Proof presses, whether existing or new, will not be subject to the standards. An "existing facility" is defined in 40 CFR 60.2 (aa). With reference to stationary source, an "existing facility" in this industry, means any rotogravure publication press which underwent construction or modification before the date of proposal of the new source performance standard; or any press which could be altered in such a way as to be of that type. An "existing facility" may become an "affected facility" and be subject to standards of performance if classified as modified or reconstructed under the provisions of 40 CFR 60.14 or 60.15, respectively. An "affected facility" in this industry is any rotogravure publication press which underwent construction, reconstruction, or modification after date of proposal for the new source performance standard.

The Clean Air Act applies to new facilities and to those modified or reconstructed as described in Subpart A, General Provisions, of 40 CFR Part 60. In general, any physical or operational change to an existing facility which causes an increase in the emission rate of volatile organic compounds (VOC) might be considered a modification. A replacement of parts of an existing facility which costs more than half of what a comparable entirely new facility would cost might be considered a reconstruction, even if emissions are not increased. The specific determination of modification and reconstruction is made on a case-by-case basis by the appropriate enforcement authority.

5.2 40 CFR PART 60 - MODIFICATION AND RECONSTRUCTION

5.2.1 Modification

Modification is defined under the provisions in Section 60.14 as follows:

> "Except as provided under paragraphs (e) and (f) of this section, any physical or operational change to an existing facility which results in an increase in the emission rate to the atmosphere of any pollutant to which a standard applies shall be considered a modification within the meaning of section 111 of the Act. Upon modification, an existing facility shall become an affected facility for each pollutant to which a standard applies and for which there is an increase in the emission rate to the atmosphere."

Paragraph (e) lists certain physical or operational changes which will not be considered as modification, irrespective of any change in the emission rate. These changes include the following:

(1) Maintenance, repair, and replacement which the Administrator determines to be routine.

(2) An increase in the production rate of an existing facility, if that increase can be accomplished without a capital expenditure as defined in Section 60.2 (bb).

(3) An increase in the hours of operation.

(4) Use of an alternative fuel or raw material, if the existing facility was designed to accommodate that alternate fuel or raw material prior to the date of the standard.

(5) The addition or use of any system or device whose primary function is the reduction of air pollutants, except when an emission control system is removed or replaced by a system which the Administrator determines to be less environmentally beneficial.

(6) The relocation or change in ownership of an existing facility (rotogravure publication press).

Paragraph (b) clarifies what constitutes an increase in emissions in kilograms per hour and the procedures for determining the increase, including the use of emission factors, material balances, a continuous monitoring system and manual emission tests. Paragraph (c) affirms that the addition of an affected facility (rotogravure publication press) to a stationary source (printing plant) does not make any other facility (rotogravure publication press) within that source (printing plant) subject to standards of performance. Paragraph (f) provides for superseding any conflicting provisions.

5.2.2 Reconstruction

Reconstruction is defined under the provisions in Section 60.15 as follows:

> "Reconstruction means the replacement of components of an existing facility to such as extent that- (1) The fixed capital cost of the new components exceeds 50 percent of the fixed capital cost that would be required to construct a comparable entirely new facility; and (2) It is technologically and economically feasible to meet the applicable standards set forth is this part".

This provision ensures that an owner or operator does not perpetuate an existing facility (rotogravure publication press) by replacing all the working components rather than totally replacing the press, in order to avoid the applicable standards of performance. The EPA, upon request, will determine if the proposed replacement of an existing facility's components constitutes reconstruction.

5.3 MODIFICATION IN A PUBLICATION ROTOGRAVURE PLANT

Most publication rotogravure presses, because of workload variations, do not operate at full capacity all of the time. As the market demand grows, the utilization of individual presses will increase. Such an increase in production to full capacity does not involve increased capital costs and would not be considered a modification. Routine maintenance, repair, and replacements, which are standard to this industry, do not increase emissions and do not constitute modifications, according to the General Provisions of 40 CFR Part 60.

These provisions also exclude substitution of alternative raw materials if the existing printing press was designed to accommodate the use of that alternative. Since most publication rotogravure presses are capable of printing on several types of paper using a variety of ink formulations, a change in substrate or ink formulation, within the capacity of the equipment, would not be considered a modification. Although a change in solvent may effect a change in emission rates, such a change is defined as not being a modification.

The emission rate also varies with the amount of ink coverage per page. This coverage varies widely and frequently, depending on customer demands and not on changes in operation procedures or equipment. Therefore, changes in ink coverage would not be considered modifications.

The addition of printing units to an existing press would be the most obvious change to be considered a modification, in this industry. A basic eight-unit press can print four colors on each side of the paper web. These colors, the primary colors, are yellow, red, blue, and black. Some presses have ten to twelve units. These presses can print an additional one or two colors on both sides of the paper. Though such a modification could be quite expensive, additional units may be added to an existing press to make it more responsive to customer demands. Some presses, which have more than eight units, are used because "last minute" production changes are possible. This feature is particularly important for advertising products. A press having more than eight units is considered a single press, providing that all the units are capable of printing simultaneously on the same continuous paper web. This definition allows such a press to operate independently, as separate web-fed sections (such as an eight unit section and a four unit section), as long as the entire press has the capability of printing on a single continuous web. Since additional units would be added to an existing press to increase its versatility, it is highly unlikely that other units of the same press would be shut down. Each unit is potentially an equal source of emissions; therefore, the addition of units would cause an incremental increase in emissions. Such an increase would be considered a modification. It is more likely, however, that a new press will be installed to provide the additional capacity.

The main air pollution control systems considered in Chapter 4 are add-on equipment. However, this industry is researching the possibilities for using waterborne inks and solvents. Any of the add-on control systems could be applied to an uncontrolled, modified press. However, fume pickup vents and ductwork, for maximizing the capture efficiency, may have to be designed a little differently than for new press. There may also be problems associated with providing a site for the new control device.

5.4 RECONSTRUCTION IN A PUBLICATION ROTOGRAVURE PLANT

According to the provisions of 40 CFR Part 60, as interpreted for the publication rotogravure industry, if the replacement of parts of an existing press cost more than half of what a new press would cost, the press is considered reconstructed. A reconstructed press may be subject to the same standards of performance as a new press, even if emissions do not increase, as a result of the reconstruction.

A major renovation which involves simultaneous replacement with identical parts of substantial portions of a press could be considered a reconstruction. If less than half of the fixed capital cost of a comparable entirely new press is incurred, the renovation could be considered routine repair providing there is no increase in emissions. This distinction could be difficult to assess. However, such a renovation is very unlikely.

Replacement of more than half the printing units of a press might be considered a reconstruction. However, since the units are essentially identical and receive essentially the same use and care, it is unlikely that only a portion of them would be replaced at one time. If extensive replacement is indicated, it is much more likely that all would be replaced. Replacement of all units would be the creation of a new facility instead of the reconstruction of an existing one.

As stated in Section 5.3, the ease of controlling an existing press depends on the effectiveness of any existing control system for that press. If the press is not currently controlled, the installation of a control system for a reconstructed press will be essentially the same as for a new press. However, this assumes the VOC vapor capture efficiency is comparable. Extensive changes may be required to improve the VOC capture efficiency of an older existing press. This fact must be considered before a decision is made to modify or reconstruct an existing press.

6. MODEL PLANTS AND REGULATORY ALTERNATIVES

6.1 GENERAL

The purpose of this chapter is to define the model plants and the regulatory alternatives that can be applied to them. Model plants are parametric descriptions of the types of plants that, in EPA's judgement, will consist of newly constructed, modified, or reconstructed affected facilities, as defined in Chapter 5. For this study, the affected facility is designated as a single publication rotogravure printing press. A typical printing press consists of eight printing units, each with individual gravure printing cylinders and dryers. The model plants consist of several production printing presses all of the same type and size. The regulatory alternatives represent various courses of action that the EPA could take towards controlling volatile organic compound (VOC) vapor emissions from rotogravure printing facilities. The model plants derived in this chapter are used in Chapters 7 and 8 to determine projected environmental, energy, and economic impacts associated with application of the regulatory alternatives considered.

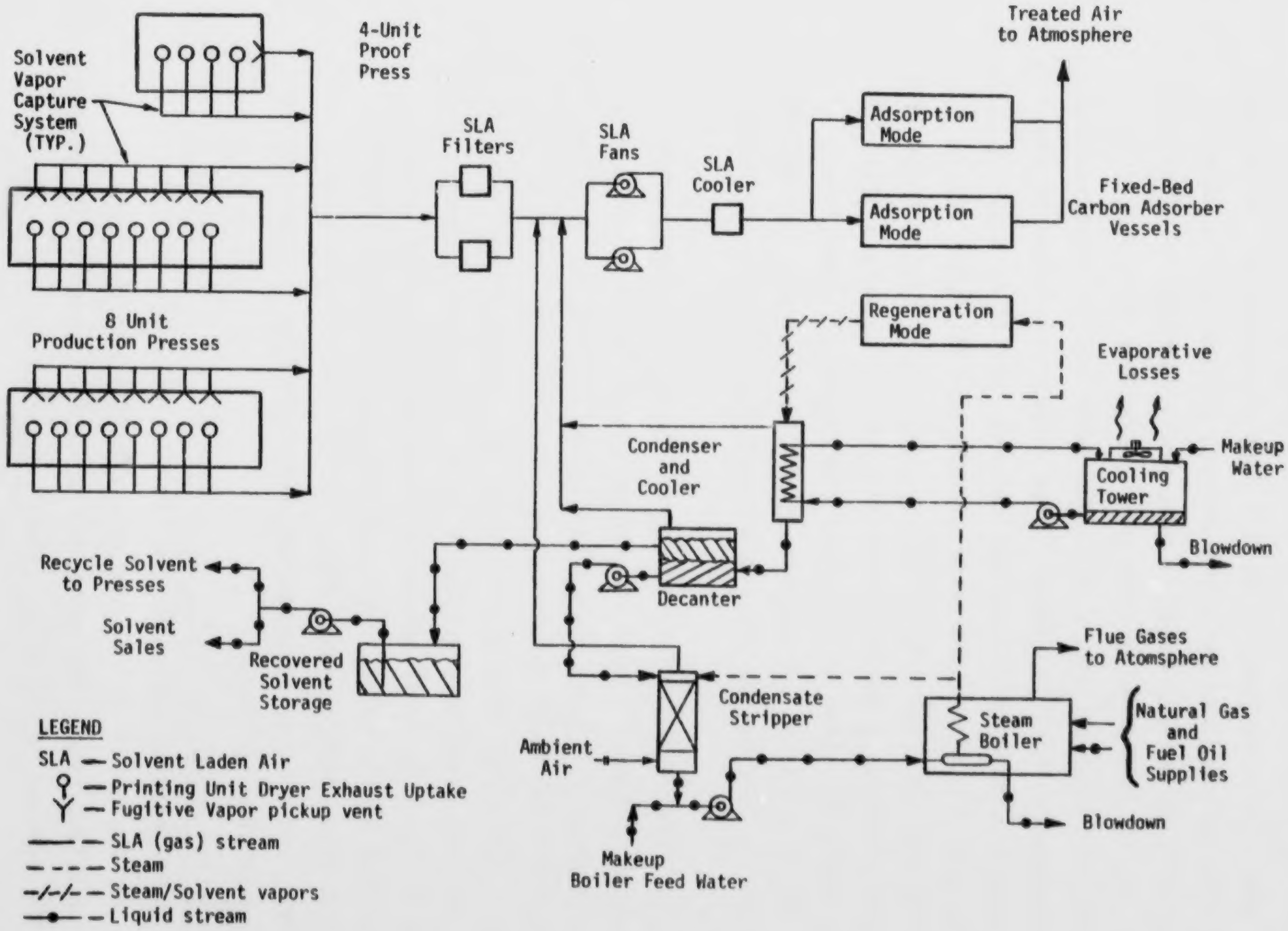
The model plants presented in this chapter represent control of VOC emissions from newly constructed printing facilities with fixed-bed carbon adsorption/solvent recovery systems. Model plants are not developed to represent emission control by any other solvent recovery systems, such as fluidized-bed carbon adsorption, because sufficient operating information for use in this industry was not available. Also, model plants are not developed for analysis of VOC emissions control by solvent destruction devices (i.e. oxidation) since these devices are not presently used and not expected to be employed in the future by this industry. Furthermore, model plants representing the use of waterborne ink systems with or without air pollution control equipment, are not analyzed since waterborne inks are not expected to be developed for this industry for another five to ten years. Finally, model plants representing modified and reconstructed existing facilities are not developed. Neither modification nor reconstruction is expected in this industry, as explained in Chapter 5.

6.2 MODEL PLANTS

Two model plants consisting of only new publication rotogravure printing presses are presented. A small model plant is assumed to consist of two production presses; a large model plant contains four production presses. Each model plant also has one proof press. These two model plants should represent most of the expected new plant expansions; however, some single press expansions may also occur. By comparison, some existing plants contain six or more production presses with two or more proof presses, as mentioned in Chapter 3. Proof presses are not considered as affected facilities, however, they are necessary standard equipment in all publication rotogravure printing plants. The model plants characterize facilities which use only solvent-borne ink systems.

The production and proof presses are considered to be of one constant size for both model plants. All production presses are assumed to be of the same width, operating at the same speed, and consisting of eight printing units each. There are some smaller and some larger existing presses; however, the press size chosen is expected to be the most common for future facilities. Most modern rotogravure presses are designed to operate at about the speed chosen for study, although older presses operate at only about half that speed. The proof presses are considered to be the same width, but consisting of only four printing units. The proof presses are operated only intermittantly and at much slower speeds compared to the production presses.

The control of VOC emissions from the model printing facilities is based on the use of solvent vapor capture systems combined with fixed-bed carbon adsorption/solvent recovery control systems, as described in Chapter 4. A diagram representing the small model printing plant incorporating a fugitive solvent vapor capture system is presented in Figure 6-1.



Solvent Vapor Capture System (TYP.)
4-Unit Proof Press
8 Unit Production Presses
SLA Filters
SLA Fans
SLA Cooler
Adsorption Mode
Adsorption Mode
Treated Air to Atmosphere
Fixed-Bed Carbon Adsorber Vessels
Regeneration Mode
Evaporative Losses
Condenser and Cooler
Cooling Tower
Makeup Water
Blowdown
Recycle Solvent to Presses
Solvent Sales
Recovered Solvent Storage
Decanter
Condensate Stripper
Ambient Air
Makeup Boiler Feed Water
Steam Boiler
Flue Gases to Atomsphere
Natural Gas and Fuel Oil Supplies
Blowdown
LEGEND
SLA — Solvent Laden Air
— Printing Unit Dryer Exhaust Uptake
— Fugitive Vapor pickup vent
— SLA (gas) stream
— Steam
— Steam/Solvent vapors
— Liquid stream

Figure 6-1. Schematic of small model publication rotogravure printing plant with fugitive solvent vapor capture systems and a fixed-bed carbon adsorption/solvent recovery control system.

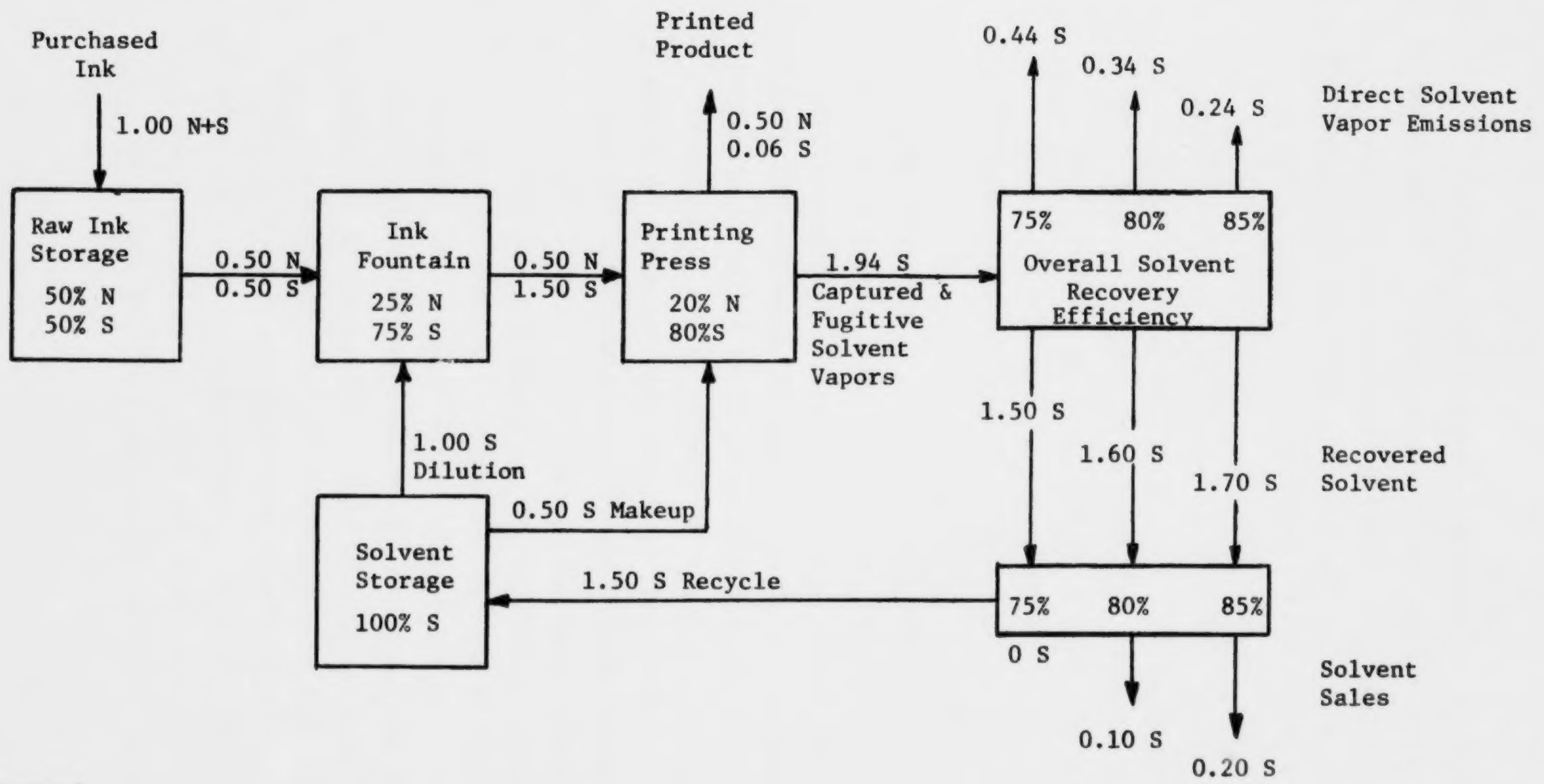
Captured solvent laden air (SLA) is drawn from the production presses, as well as from the proof press, and through a filter by the SLA fan. A spare filter and fan are included. The SLA from proof presses is included to conservatively oversize the emissions control system, even though the solvent consumption by these presses is very small compared to production presses. The SLA is then directed through a cooler and distributed to multiple fixed-bed carbon adsorbers, with one spare bed for regeneration mode. The recovered solvent is assumed to be directly recycled to the presses, as needed, with excess recovered solvent serving as a by-product for sale to the ink manufacturer or others. All model plants include a waste water stripping operation to remove most of the dissolved solvent content and recycle the resultant stripped condensate as make-up feed water to the plant steam boiler. The condensate stripper is a steam heated vertical packed column made of stainless steel. The solvent stripping medium is provided by ambient air pulled up through the column by the SLA fan.

Several utilities are required for operation of fixed-bed carbon adsorption control systems. Steam for regenerating the carbon beds and heating the condensate stripper is provided by an on site boiler. The boiler is assumed to be fired by natural gas half the time and fuel oil half the time. The boiler flue gas emissions are vented directly to the atmosphere. Cooling water is provided by an on site cooling tower. Make-up water for cooling tower and boiler blowdowns and other water losses is provided by the normal plant water supply. Electricity for running the SLA fans, miscellaneous pumps, boiler and cooling tower support systems, and control instrumentation is provided by power supply generated from offsite facilities.

6.2.1 The Printing Operation

The two main printing operation characteristics which identify the model plants are the hourly production rate capacity and the press operating or printing time. The potential production capacity is described in terms of the average hourly total solvent consumption rate. The plants' solvent usage capacity is directly related to the number of production presses, the press widths, and the press speeds. As described in Chapter 3, the raw ink composition, the ink coverage, and the paper weight all vary for each production run; however, the mixed ink consumption as applied to the gravure printing cylinder must be controlled within a narrow range for good quality gravure printing. Consequently, total solvent consumption is the best indicator of production capacity. Since the production presses are assumed to be all the same size, the large model plant then consumes twice as much solvent as the small plant. The yearly average press printing time is assumed to be 65 percent of the scheduled operating time. This assumption is based on the plant test data presented in Appendix C, as explained in Chapter 3, combined with industry information on historical operations.[1,2]

The potential amount of VOC emissions are equal to the total amount of solvent consumed in the printing process. The total amount of solvent includes the solvent in the raw inks, solvent in any extenders/varnishes used, and the solvent added at the press. A general volumetric relationship among raw ink usage, recycled recovered solvent, total solvent consumption, and expected emissions at three overall VOC control levels is presented in Figure 6-2. Raw ink, as purchased, typically averages about 50 volume percent solvent and 50 volume percent nonvolatile components. The raw ink is then diluted in a one-to-one volume ratio with solvent. For simplicity, extender/varnish quantities are not shown as these are usually very small compared to the raw ink usage. A solvent make-up allowance is included to cover evaporative losses from the ink fountain. The resultant 80 percent solvent volume ink mixture applied at the press is typically the composition required to control ink viscosity for high quality gravure printing. All of the nonvolatile ink components and about three percent of the total solvent used leave the press with the printed product (see Chapters 3 and 4). These product retained solvents are considered VOC air pollutants since they will eventually evaporate from the product. Finally, the material balance shows the amount of


Purchased Ink
1.00 N+S
Raw Ink Storage
50% N
50% S
0.50 N
0.50 S
Ink Fountain
25% N
75% S
0.50 N
1.50 S
Printing Press
20% N
80%S
Printed Product
0.50 N
0.06 S
1.94 S
Captured & Fugitive Solvent Vapors
75%
80%
85%
Overall Solvent Recovery Efficiency
0.44 S
0.34 S
0.24 S
Direct Solvent Vapor Emissions
1.50 S
1.60 S
1.70 S
Recovered Solvent
75%
80%
85%
0 S
0.10 S
0.20 S
Solvent Sales
1.50 S Recycle
Solvent Storage
100% S
1.00 S Dilution
0.50 S Makeup

Legend

N - Volume quantity of nonvolatile ink components (resins, pigments, varnish)
S - Volume quantity of liquid solvent (or equivalent liquid volume of solvent vapors)
Basis: - Recovered solvent at the same temperature as solvent and ink used at the press
- Three percent of solvent retained in printed product
- Total solvent vapor emissions include direct vapor emissions from control device outlet losses and fugitive press losses, as well as solvent retained in product

Figure 6-2. Schematic ink and solvent volume material balance around a publication rotogravure model printing facility with solvent recovery control at three regulatory alternative levels.

surplus or by-product recovered solvent (for sales) at the three overall control levels. Overall control pertains to the total amount of solvent used at the press. The solvent volume balance is based on the assumption that the recovered solvent is at the same density (i.e. temperature) as the solvent used at the press.

6.2.2 Model Plant Parameters

Three regulatory alternatives are applied to each model plant size considered. The regulatory alternatives considered result from variations in both capture and carbon adsorber efficiencies. The basis for the regulatory alternatives that were chosen is explained in a later section. A complete description of the resulting six model plant cases is presented in Table 6-1. The following assumptions were used to calculate the material balances for each case:

- Only dryer exhaust solvent vapors are captured for the 75 and 80 percent overall control efficiency cases. The SLA flow rate for each unit represents typical modern design practice to maintain the organic vapor concentration at about 20 percent of the lower explosive limit (LEL) level.[3,4,5,6]
- Fugitive solvent vapors are captured with the dryer exhausts for the 85 percent overall control efficiency cases. The fugitives capture-air flow is based on the design air flow rate through the Meredith/Burda cabin enclosure.[7]
- Typical total solvent volume consumption capacity rate for each production press is 454 liters/hr (120 gallons/hr).[8,9] The actual average usage rate is about only 65 percent of the capacity because of frequent press shutdowns, as explained in Chapter 3.
- Typical raw ink volume usage is based on the two-to-one volume ratio of total solvent consumption to raw ink usage shown in the general material balance schematic presented in Figure 6-2.
- The solvent used is a typical naphtha-based (lactol spirits) mixture consisting of the components described in Chapter 7, with an average liquid density of 0.742 kg/liter (6.2 lbs/gallon).[10,11,12]

TABLE 6-1. MODEL PLANT PARAMETERS

Plant Size	Small	Small	Small	Large	Large	Large
Production Presses/units	2/8 units each	2/8 units each	2/8 units each	4/8 units each	4/8 units each	4/8 units each
Press data						
Speed, m/s (ft/min) Web width, m (in)	10.16 (2000) 1.83 (72)	10.16 (2000) 1.83 (72)	10.16 (2000) 1.83 (72)	10.16 (2000) 1.83 (72)	10.16 (2000) 1.83 (72)	10.16 (2000) 1.83 (72)
Average overall control efficiency	75%	80%	85%	75%	80%	85%
Average control device efficiency	90%	95%	95%	90%	95%	95%
Average Capture Efficiency	84%	85%	90%	84%	85%	90%
Approximate operating time (65% of scheduled)	4740 hrs/yr	4740 hrs/yr	4740 hrs/yr	4740 hrs/yr	4740 hrs/yr	4740 hrs/yr
Typical design SLA[a] dryer/fugitive flow rate (per unit, production press)						
Flow, Nm³/hr (SCFM)	4250/0 (2500/0)	4670/0 (2750/0)	4250/2125 (2500/1250)	4250/0 (2500/0)	4670/0 (2750/0)	4250/2125 (2500/1250)
Estimated SLA flow rate (proof press)						
Flow, Nm³/hr (SCFM)	16,990 (10,000)	16,990 (10,000)	16,990 (10,000)	16,990 (10,000)	16,990 (10,000)	16,990 (10,000)
Estimated design SLA bulk conditions (to control system)						
Flow, m³/hr (ACFM) Concentration[b], g/m³ (ppmv) Temperature, °C (°F)	90,560 (53,300) 7.45 (1980) 41 (105)	97,800 (57,560) 7.20 (1920) 41 (105)	126,790 (74,620) 5.60 (1480) 41 (105)	163,020 (95,940) 7.45 (1980) 41 (105)	177,510 (104,470) 7.20 (1920) 41 (105)	235,490 (138,590) 5.60 (1480) 41 (105)
Typical raw ink consumption, l/hr (gal/hr)	456 (120)	456 (120)	456 (120)	912 (240)	912 (240)	912 (240)
Typical mixed ink consumption, l/hr (gal/hr)	1136 (300)	1136 (300)	1136 (300)	2272 (600)	2272 (600)	2272 (600)
Typical total solvent consumption l/hr (gal/hr)	908 (240)	908 (240)	908 (240)	1816 (480)	1816 (480)	1816 (480)
Potential emissions @65% on-line factor, Mg/yr (tons/yr)	3198 (3525)	3198 (3525)	3198 (3525)	6396 (7050)	6396 (7050)	6396 (7050)
Expected emissions[c] with controls, Mg/yr (tons/yr)	798 (880)	640 (705)	473 (530)	1596 (1760)	1280 (1410)	946 (1060)

[a] SLA - solvent laden air

[b] The actual operating concentration varies greatly with operating conditions (estimated to be 85% of design).

[c] These figures assume that any solvent initially retained in the printed product is an air pollutant.

- Solvent vapor concentration in the SLA to the control system is determined from the cumulative SLA flow rate from the production presses combined with the assumed captured amount of evaporated solvent.
- Ink and solvent usage by proof presses is negligible and not included,
- Typical scheduled press operation time is about 7,296 hrs/yr, based on 24 hrs/day, six operating days/week, with eight holidays/hr.

6.2.3 Solvent Vapor Capture System

The purpose of the solvent vapor capture system is to gather the VOC vapors emitted from the presses and direct these vapors to the control device. The ultimate efficiency of any capture system is limited by the amount of solvent retained in the printed product and by the numerous fluctuations in the rotogravure printing process, as explained in Chapters 3 and 4. The capture efficiency used for each model plant case presented in Table 6-1 is the average long-term efficiency that is expected for printing the full range of products handled in this industry.

Three capture efficiencies are used for the development of the six model plant cases. The lowest capture efficiency is assumed to be about 84 percent. This represents capturing just the dryer exhausts from the least expensive, older-type design printing presses. These press designs allow fugitive emissions to occur by solvent vapor losses from open areas of the press, exposing parts of the ink fountain, the gravure printing cylinder, and the paper web. A typical capture-air flow rate of 4250 Nm^3/hr (2500 SCFM) is assumed for each printing unit dryer. As explained in Chapters 3 and 4, the pressroom is ventilated with roof or peripheral fans discharing fugitive vapors directly to the atmosphere with these type press capture designs.

The second capture efficiency is assumed to be slightly higher at about 85 percent. This represents capturing just the dryer exhausts from more expensive, modern-design presses. These newer designs help to minimize fugitive vapor losses by enclosing the ink fountain and extending the lower end of the enclosed dryers down closer to the printing cylinder along with about a ten percent increase in the dryer air flow rate. Pressroom ventilation is required for this type capture design also.

The highest capture efficiency is assumed to be at least 90 percent. This represents capturing the dryer exhausts from modern-design presses along with most of the fugitive vapors emitted from the presses. The total capture-air flow rate for each printing unit is increased by 50 percent over that for the older-type press designs. For these model plant cases, pressroom ventilation is not required. The fugitive vapors are assumed to be captured by --

- A partial enclosure fugitive vapor capture system that is vented to the control device; or
- A system of multiple fugitive vapor capture vents that are located around the press and collectively ducted to the control device; or
- Total pressroom ventilation air that is directed to the control device.

An ideal solvent vapor capture system, which is not considered in the model plants, would be designed to further concentrate the solvent vapors in the dryer exhausts. As explained in Chapters 3 and 4, technology and instrumentation are available to control and safely concentrate the organic vapors in the dryer exhaust SLA to about 50 percent of the lower explosive limit (LEL) level. This practice could minimize the SLA volumetric flow rate that must be handled. In comparision, the dryer exhaust SLA vapor concentrations shown in Table 6-1 are at the 19 to 20 percent of LEL level. Therefore, the model plant emissions control systems are conservatively oversized. This capture design feature is not included in the model plants because solvent vapor analyzer/controllers are generally not presently utilized in this industry. The plant personnel feel that they would rather handle an excess amount of air to be safe instead of minimizing the air flow rate for decreasing the required size of the emission control equipment and increasing the control device efficiency.

6.2.4 Solvent Laden Air Treatment

Fixed-bed carbon adsorption/solvent recovery systems are used as the emission control devices for all model plants. The average efficiency of these control devices is limited by the design solvent vapor concentration in the SLA treated, as well as wide variations in the vapor concentrations caused by fluctuations in the printing process. The control device efficiency used for each model plant case presented in Table 6-1 is the average long-term efficiency that is expected over normal printing periods, as well as during the numerous routine press shutdowns.

Two control device efficiencies are used for the development of the six model plant cases. The lowest efficiency is assumed to be about 90 percent; the highest efficiency is assumed to be at least 95 percent. The lower efficiency represents the performance of the least expensive, older-type design carbon adsorber systems. The higher efficiency represents the performance of the more expensive, modern-design adsorbers. These control device efficiencies are thoroughly discussed in Chapter 4.

As shown in Figure 6-1, the model plants include an extra carbon bed vessel. This extra vessel is required for all fixed-bed adsorber systems to allow for the regeneration mode, while the other vessels handle the full SLA flow rate.

6.3 REGULATORY ALTERNATIVES

Three regulatory alternatives were considered. These alternatives call for an overall reduction of VOC emissions at 75, 80, and 85 percent levels. These three alternatives were selected to represent the various emission control levels which are achievable, based on the discussion of the emission control techniques in Chapter 4. The three alternatives were applied to the two plant sizes considered to develop the six model plant cases shown in Table 6-1. The overall VOC control efficiency is equal to the capture efficiency times the emission control device efficiency. As previously mentioned, regulatory alternatives were not developed specifically to represent VOC emissions reduction by low-VOC, waterborne ink system usage.

The 75 percent overall control level represents capturing and treating the dryer exhausts from the least expensive, older-type design presses with the lowest cost, older-type design carbon adsorber systems.

This is considered to be the baseline control level. This corresponds to the control techniques guidelines (CTG) recommendation for existing rotogravure printing facilities, which the states are expected to use in revising their State Implementation Plants (SIP).[13] This control level is achievable by capturing about 84 percent of the potential solvent vapors from the press with a 90 percent adsorber efficiency.

The 80 percent overall control level represents capturing the dryer exhausts from new, well-designed presses. In this case 85 percent capture would be required with a 95 percent efficient adsorber. This corresponds to a typical, well controlled modern facility. Overall VOC emission reductions of 80 to 84 percent were determined from short term test data and five months of plant data at Texas Color Printers plant.[14,15,16] In addition, over four months of plant data from World Color Press showed four-week average overall VOC control efficiencies ranging from 78 to 84 percent.[17]

The 85 percent regulatory alternative represents capturing the dryer exhausts from modern-designed presses, as well as some of the fugitive solvent vapors. This is intended to correspond to about 90 percent capture of the solvent vapors emitted from the facilities with a 95 percent efficient adsorber. The results of operating data obtained from the Meredith/Burda, Texas Color Printers, and Standard Gravure plants are discussed in Chapter 4. The analysis presented in Chapter 4 shows the following:

- The Meredith/Burda overall VOC emission control efficiencies, after adjustment for density (temperature) correction and infiltration of solvent vapors, are --
  - -- 89 to 91 percent by short-term tests; and
  - -- 84 to 91 percent by monthly plant data.
- The Texas Color facilities could potentially achieve about 88 percent overall VOC control by directing their ventilation-floor sweep vents into the carbon adsorber system, rather than to the atmosphere.

- The four-week average overall VOC control efficiencies reported by the Standard Gravure plant range from 85 to 90 percent.[18,19]

The data base shows that application of the best demonstrated technology will achieve about 90 percent overall VOC control at times, with certain type products. However, only about 85 percent overall control is achievable in the typical plants in this industry when printing some other products. The 85 percent control level is the maximum that can be expected to be continually achieved. This regulatory alternative allows for expected efficiency variations in both the capture and adsorber systems, combined with larger amounts of solvent retained by some printed products.

The resultant expected annual emissions from application of each regulatory alternative is shown in Table 6-1. The reduction in solvent emissions or amount of recovered solvent is equal to the difference in potential and expected emissions. The potential emissions are the annual amounts of total solvent consumption, assuming actual press operation at 65 percent of scheduled time.

The environmental and energy impact analyses of the VOC emission control systems for the six model plant cases is presented in Chapter 7. The economic impact analyses are presented in Chapter 8.

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19. Harvin, R.L. Recovery and Reuse of Organic Ink Solvents. (C&I/Girdler, Inc. Louisville, KY. (Presented at the Conference on Environmental Aspects of Chemical Use in Printing Operations. King of Prussia. Sept. 22-24, 1975). 25 p.

7. ENVIRONMENTAL AND ENERGY IMPACTS

As discussed in Chapter 3, the volatile organic compounds (VOC) emissions from a rotogravure publication printing plant result from the evaporation of the printing solvent. This solvent originates from the purchased ink, extenders, and varnishes, and the solvent which is added to the ink at the press. A small amount of additional solvent is used for cleanup purposes. In an uncontrolled plant the entire amount of solvent is vented to the atmosphere.

Emission control techniques were identified in Chapter 4 as possible candidates for the emission control system. Carbon adsorption using fixed adsorption beds represents the most popular method. In the past, some states did not require the use of an emission control system if a "non-photochemically" reactive solvent was used. Presently, the states are governed by new State Implementation Plans (SIP's). These SIP's are based on a Control Techniques Guideline (CTG) document[1] for this industry. The CTG recommends at least a 75 percent overall reduction from existing sources in oxidant non-attainment areas.

Fixed-bed carbon adsorption systems are commonly used in the industry. Typical existing systems, however, have a lower overall control efficiency than that of a system which might be considered the best-demonstrated control system.

Incineration has not been used by the publication rotogravure industry because it is more economical to recover the solvent. The first fluidized carbon bed system to be used by the publication rotogravure industry in this country began operation in 1979. No operating data on this system is available.

In this chapter, the air, water, solid waste, and noise pollution impacts, as well as energy impacts are examined for the three regulatory alternatives described in Chapter 6. These impacts are examined for individual model plants and for the nationwide effect.

7.1 AIR POLLUTION IMPACT

7.1.1 Emissions From Rotogravure Publication Printing Plants

Emission estimates discussed in Chapter 3 indicate that about 56,800 Mg (62,600 tons) of solvent were emitted to the atmosphere by the publication rotogravure printing industry in 1977. Of this total, about 44,400 Mg (49,000 tons) were emitted from uncontrolled sites. The total potential emissions during this period were about 137,200 Mg (151,200 tons). Considering recent trends in the industry, it is assumed that if no New Source Performance Standards (NSPS) are promulgated by the EPA, state regulations and economic considerations will require CTG provisions for at least a 75 percent overall reduction of VOC emissions. If a 75 percent control were applied to the uncontrolled sources, the 1977 total emissions would have been reduced to about 23,500 Mg (25,900 tons).

The seven percent growth projections discussed in Chapters 3 and 8 indicate that the output of the publication rotogravure printing industry will almost double between 1976 and 1986. Table 7-1 illustrates the air pollution impact resulting from the implementation of NSPS at the three different levels of control. The NSPS proposal date is set for mid-1980. Estimated emissions during the five-year period from 1981 to 1985 are illustrated in this table. The estimates assume that all presses installed before 1980 would be controlled at only the 75 percent level. Only the new "affected" presses would be controlled at the two higher levels.

7.1.2 Primary Air Pollution Impacts

7.1.2.1 Chemical Composition. In some instances, toluene is used alone as the solvent in a publication rotogravure facility, but the solvent most used by the industry is a petroleum fraction which distills in the 93-127°C (200-260°F) range. This solvent fraction is commonly called VM&P naphtha, lactol spirits, or one of several trade names.[2,3,4] It consists mainly of C_6 to C_7 paraffins and cycloparrafins, and C_7 to C_8 aromatics, namely toluene, xylene, and ethylbenzene. Benzene and olefin content are very low and are carefully limited.

The solvent compositions used by the printers varies according to the ink used and other printing conditions. Where state regulations specify a "nonphotochemically reactive" or low photochemical reactive solvent, the

TABLE 7-1. ESTIMATED VOC EMISSIONS FROM PUBLICATION ROTOGRAVURE PRINTING INDUSTRY AT THREE ALTERNATIVE NSPS LEVELS, Mg/yr (tons/yr)

Year	Potential Uncontrolled Emissions[a]	NSPS Overall Control Levels[b]		
		75%	80%	85%
1977	137,000 (151,000)	34,300 (37,800)[c]	—	—
1979	157,000 (173,000)	39,300 (43,300)	—	—
1980	168,000 (185,000)	42,000 (46,300)	41,500 (45,700)	41,000 (45,100)
1981	180,000 (198,000)	45,000 (49,600)	43,900 (48,300)	42,800 (47,000)
1985	236,000 (260,000)	59,000 (65,000)	55,000 (60,600)	51,100 (56,300)

[a] Seven percent annual real growth rate assumed.

[b] All presses installed before 1980 controlled at only the 75% level. New Source Performance Standards (NSPS) affect only new presses installed during or after 1980.

[c] Actual 1977 VOC emissions were about 56,800 Mg (62,600 tons), representing an Industrywide overall control average of about only 60 percent.

aromatic content is limited to less than 20 percent. In many instances the aromatic content is limited to less than 20 percent due to high toluene and xylene levels. The blending of naphtha, toluene, and xylene affect the drying rate of the solvent. Xylene retards the drying, while naphtha hastens it.

7.1.2.2 Photochemical Characteristics. It is a well-known fact that the major cause of smog is photochemical reaction which starts with the organics in the air and ends up with a cloud of irritating chemicals. The VOC emitted from this industry, in the presence of NO_x (nitric oxide or nitrogen dioxide) and ultraviolet irradiation (sunlight), can react to form various toxic compounds, such as aldehydes, ketones, PAN, ozone, and other oxidants. Thus, the toxicity of the solvent component vapors is regarded as of lesser importance than the toxicity of their reaction products. This effect is very pertinent to the study of this industry since most of the printing plants are located within or very close to urban areas. Therefore, reduction in VOC emissions would result in less formation of smog and irritating chemicals.

In the early 1970's many SIP's similar to Los Angeles' Rule 66 were promulgated. These SIP's allowed the substitution of "nonphotochemically reactive" solvent for "photoreactive" solvent as an acceptable control method. Many of these SIP's allow unlimited emission of "nonphotochemically reactive" material. According to their definitions, only the aromatics used by the rotogravure industry are considered "photochemically reactive".

However, recent reactivity studies indicate that though they are not as reactive as the aromatics, the C_{4+} paraffins and cycloparaffins react in the atmosphere to form significant amounts of ozone.[5,6] Their reactivities have been estimated to be about one-third to one-half that of toluene at a hydrocarbon-to-NO_x ratio of 2, considered typical for an urban environment. These reactivities appear to increase as the HC/NO_x ratio increases.[7]

On the basis of these studies, the EPA has acknowledged that if Rule 66 were revised to be consistent with current knowledge of reactivity, the solvent substitution option would be eliminated for most sources which now use it.[8] For these reasons, the solvent composition is not expected to play any significant role in the development, promulgation, or enforcement of NSPS for this industry.

7.1.2.3 Toxicities. The toxic properties of the components in the typical mixed solvents are important considerations for the workers and operators in the pressroom of the printing plants, as well as for the surrounding environment outside the plants. Adequate ventilation is required to maintain the solvent vapor concentrations in the pressroom air below the OSHA regulation levels. In addition, Threshold Limit Values (TLV), which are equal to or below OSHA levels, have been recommended as health hazard guidelines by the American Conference of Governmental Industrial Hygienists (ACGIH), a private organization. Measurements during tests at the Texas Color plant showed that the ventilation air discharged directly to the atmosphere from pressrooms can contain solvent vapor concentrations ranging from about 200 to 400 ppm (V/V). The dryer exhausts solvent laden air (SLA) vapor concentrations can range from a low of about 1500 ppm to a maximum, allowed by insurance guidelines of up to about 5,000 ppm, depending on the solvent blend. In an uncontrolled plant, both the dryer exhausts and ventilation air are discharged directly to the atmosphere. These vents are usually located on the plant roof to help disperse and dilute the solvent vapors. However, the solvent vapors, being heavier than air, will have a tendency to settle back to the ground. The locations at which the solvent vapors may settle or concentrate in the surrounding environment depend upon the atmospheric conditions.

The toxic effects of several representative mixed solvent airborne component vapors are presented in Table 7-2. Toluene is considered a more powerful narcotic and more acutely toxic than is benzene. However, benzene has been shown to pose a greater long term health hazard and has, therefore, been essentially eliminated from rotogravure solvents. The acute toxicities of xylene and ethylbenzene are considered comparable to each other and greater than that of toluene. No studies have been made on the chronic toxicities of xylene and ethylbenzene in man. Normal paraffins in the C_6 and C_7 range are classified as central nervous system depressants.

TABLE 7-2. TOXIC EFFECTS OF REPRESENTATIVE ROTOGRAVURE SOLVENT COMPONENT VAPORS IN AIR[9, 10, 11, 12]

Vapor Concentration (ppm)	Toluene	Commercial xylene	Ethyl benzene	N-Heptane	N-Hexane	Cyclohexane	Methylcyclohexane
100	• TLV	• OSHA TWA • TLV	• OSHA TWA • TLV		• TLV		
174		• Affects central nervous system in mice.					
200	• OSHA TWA • Fatigue, confusion, parenthesias of skin in man after 8 hrs.		• Acute eye irritation in man, intensity of 1 or 2.				
300	• OSHA Ceiling • Above symptoms more pronounced.					• OSHA TWA • TLV	
400	• Mental confusion in man after 8 hrs.			• TLV			• TLV
500				• OSHA TWA	• OSHA TWA		• OSHA TWA
600	• Extreme confusion, exhilaration, nausea, dizziness in man after 3 hours, symptoms more pronounced after 8 hrs. • Dilated pupils, incoordination, insomnia after 8 hrs.						
786						• Liver and kidney changes in rabbits after 6 hrs/day, 50 days.	

TLV = Threshold limit value, TWA recommended by ACGIH
TWA = 8-hour time weighted average exposure.

(continued)

TABLE 7-2 (continued).

Vapor Concentration (ppm)	Toluene	Commercial xylene	Ethyl benzene	N-Heptane	N-Hexane	Cyclohexane	Methylcyclohexane
1000			• Acute eye irritation in man, intensity of 3.	• Slight vertigo in man after 6 minutes.			
1150		• Decreased leukocytes and red blood cells, increased platelets in rabbit after 8 hr/day, 6 days/week for 55 days.					
2000			• Acute severe eye irritation, lacrimation, irritation of nasal membranes in man. • Dizziness in man after 6 minutes.	• Slight vertigo in man after 6 minutes.	• No symptoms in man after 10 minutes.		
2700	• Acute prostration in mice.						
3300							• Minor kidney and liver injury in rabbits after 5 hrs/day, 70 days.
3500			• Acute prostration in mice.				
4000	• Death in animals after a few 4-hour exposures.						
4700		• Acute prostration in mice.					
5000	• 50% fatalities in mice after 8 hrs.		• Intolerable acute irritation of eyes and nasal membranes in man.	• Marked vertigo, hilarity, incoordination in man after 4 minutes (no irritation of mucous membranes). • Uncontrolled hilarity or stupor in man after 15 minutes.	• Dizziness in man after 10 minutes.		

Toxicities of branched paraffins in the C_6 to C_7 range are generally unknown, but these substances are suspected to have narcotic or anesthetic properties. Cycloparaffins have a narcotic effect on the human body.[13] Methyl cyclohexane is considered three times as toxic as hexane. Little is known of the chronic toxicities of the cycloparaffins.[14] The toxicities of other components are assumed to be similar. No data on the toxicity of the entire solvent mixture has been found in the literature. This table shows that although toluene, xylene, and ethylbenzene are obviously toxic, other components of the publication rotogravure solvent may also be health hazards.

7.1.3 Secondary Air Pollution

Emissions of air pollutants from two secondary sources result from the generation of energy required for operation of fixed-bed carbon adsorption control systems. The main source of secondary air pollution results from the fuel combustion to produce steam. The steam is used to regenerate the carbon beds and recover the solvent, at an assumed constant ratio of 4 Kg steam per Kg recovered solvent. The steam boilers are located on the plant site. Secondary air pollutants also result from electrical power generation. The electrical power is required to drive the large SLA fans, cooling tower pumps and fans, boiler pumps and air fans, and all emission controls instrumentation. The electrical power plants are separate off-site facilities.

The relationship between secondary air pollutant emissions from steam production and the reduction in primary VOC emissions, or recovered solvent, is presented in Table 7-3 for the three overall control levels considered. Estimates are presented for large model plants only, with projections for nationwide impacts in the year 1985. Total secondary emissions consist of particulate matter, carbon monoxide, unburned hydrocarbon, sulfur oxide (SO_x) and nitrogen oxide (NO_x) components in the flue gases from the boiler combustion chambers. The resulting fuel combustion emissions are estimated from published factors for uncontrolled industrial boilers.[15,16] The boilers are assumed to be fired by distillate grade fuel oil with a one weight percent sulfur content half of the

TABLE 7-3. SECONDARY AIR POLLUTION IMPACTS OF STEAM PRODUCTION AND ELECTRICAL POWER GENERATION FOR CONTROL OF VOC EMISSIONS BY FIXED-BED CARBON ADSORPTION/SOLVENT RECOVERY IN THE PUBLICATION ROTOGRAVURE INDUSTRY, Mg/yr (tons/yr)[a]

Items	Overall Solvent Recovery Efficiency						Incremental VOC Control	
	75%		80%		85%		75%-85%	
	Steam	Electrical Power	Steam	Electrical Power	Steam	Electrical Power	Steam	Electrical Power
Secondary "HC" emissions for large model plant:[b]	0.13 (0.14)	-- --	0.14 (0.16)	-- --	0.15 (0.17)	-- --	0.02 (0.03)	-- --
Total secondary emissions for large model plant:[c]								
Separate:	18.72 (20.58)	5.41 (5.96)	19.98 (21.96)	5.97 (6.58)	21.23 (23.35)	8.12 (8.95)	2.51 (2.77)	2.71 (2.99)
Combined:	24.08 (26.54)		25.90 (28.54)		29.30 (32.30)		5.22 (5.76)	
Estimated recovered solvent from large model plant:[d]	4800 (5290)		5120 (5640)		5450 (5990)		650 (700)	
Projected national total secondary emissions for 1985:[e]								
Separate:	691 (760)	200 (220)	706 (776)	211 (233)	720 (792)	276 (304)	29 (32)	76 (84)
Combined:	890 (980)		915 (1,009)		995 (1,096)		105 (116)	
Projected national recovered solvent for 1985:[f]	177,110 (194,820)		181,050 (199,160)		184,990 (203,490)		7,880 (8,670)	

[a] Steam production by uncontrolled on-site steam boilers fired by distillate grade fuel oil 50% of the time and by natural gas 50% of the time - Reference 15,16; electrical power from controlled off-site coal-fired utilities (worst case) - Reference 17,18.

[b] Unburned hydrocarbons in flue gases

[c] Total flue gas pollutants: particulate matter, SO_x, HC, and NO_x

[d] See Table 6-1, difference between potential and expected emissions

[e] Scaled-up by ratio of total secondary emissions to recovered solvent from large model plant

[f] See Table 7-1, difference between potential and estimated VOC emissions

time, and by natural gas half the time. An 80 percent thermal efficiency is assumed for each fuel usage. Sulfur oxides (SO_x) are the major pollutants in the flue gases from fuel oil combustion; however, nitrogen oxides (NO_x) are the major pollutants of concern when burning natural gas. In the future, however, flue gas emissions from new industrial boilers should be much lower than estimated in order to comply with federal emission standards now being developed. In Table 7-3, the total secondary air pollutant emissions increase in a direct proportion with increased overall reduction in primary VOC emissions. This is because of the constant factors for steam usage to recovered solvent and flue gas emissions per unit of fuel combustion.

The relationship between secondary air pollutant emissions from electrical power generation and the reduction in primary VOC emissions is also presented in Table 7-3. An estimate of the quantity and type of air pollutant emissions from electrical utilities is more complex, however, because of the wide range of processes and fuel resources used (e.g., coal, fuel oil, natural gas, nuclear power, waterpower). As a worst case estimate, the electrical power is assumed to be generated by coal-fired utilities. The coal is assumed to be Illinois No. 6 bituminous grade with 3.5 weight percent sulfur and 12.3 weight percent ash content. The direct flue gases from the coal combustion were first determined from published factors for uncontrolled electric utility steam boilers which use the wet bottom pulverized process.[17] However, fuel combustion emissions from these utilities are regulated under federal air pollution standards.[18] Therefore, the resulting fuel combustion emissions are estimated for controlled utilities in compliance with the federal emission standards. Sulfur oxides (SO_x) and nitrogen oxides (NO_x) are the major pollutants in the flue gases from the controlled utilities.

7.1.4 Air Pollution Impact Summary

A very favorable air pollution impact is associated with the implementation of carbon adsorption equipment in this industry. The potential VOC vapor emissions from this industry, for the year 1985, are projected to be about 236,000 Mg (260,000 tons). If all facilities were controlled at the 75 percent baseline-level, the resulting emissions would be about

59,000 Mg (65,000 tons) per year. The emissions would be reduced by about an additional eight percent, if all new facilities were controlled at the 80 percent level, with existing facilities controlled at the 75 percent level. Similarly, the emissions would be reduced by about an additional 13 percent over baseline control level, if all new facilities were controlled at the 85 percent level.

Emissions of air pollutants from two secondary sources result from the operation of carbon adsorption control systems. However, as shown in Table 7-3, the total secondary air pollutants are estimated to represent only about 0.5 percent of the corresponding VOC emission reduction from the publication rotogravure presses. Moreover, hydrocarbon vapors makeup less than one percent of these total secondary emissions. The only combustion emissions of any significance are oxides of sulfur and nitrogen. Even these emissions are very low. In conclusion, the resulting total air pollutants emitted from secondary sources are expected to represent only a very slight offsetting effect for control of VOC emissions from publication rotogravure presses.

7.2 WATER POLLUTION IMPACT

There are three potential sources of water pollution associated with the model plants developed in Chapter 6. The largest source is the dissolved solvent in the condensate discharged from the decanter section of the carbon adsorption system. This condensate typically contains from 130 to 200 ppm solvent, but can be as high as 1,900 ppm solvent, depending on the solvent used and the temperature.[19,20] Potential impact estimates representing condensate discharged untreated from the model plants and projections for the year 1985 are presented in Table 7-4 for each regulatory alternative considered. The estimates are based on the assumption that only new "affected" presses would be controlled at the higher regulatory levels, as explained in Section 7.1.1. Comparison of the results of Tables 7-3 and 7-4 show that the discharged organic solvent content corresponds to less than 0.1 percent of the respective VOC emission reductions, recovered solvent, from the presses. Also, this potential water pollution source could be virtually eliminated by air-stripping the condensate and recycling the resultant solvent-free

TABLE 7-4. POTENTIAL WATER POLLUTION IMPACTS FOR VOC EMISSION CONTROL ON MODEL PLANTS BY FIXED-BED CARBON ADSORPTION/SOLVENT RECOVERY SYSTEMS*

Items	Overall Solvent Recovery Efficiency			Incremental VOC Control
	75%	80%	85%	75% - 85%
Small plants				
Total discharge flow, 10^6 liters/yr (10^6 gallons/yr)	9.60 (2.52)	10.24 (2.72)	10.92 (2.88)	1.32 (0.36)
Organic solvent content, Mg/yr (tons/yr)	1.84 (2.00)	1.96 (2.16)	2.08 (2.28)	0.24 (0.28)
Large plants				
Total discharge flow, 10^6 liters/yr (10^6 gallons/yr)	19.20 (5.08)	20.48 (5.40)	21.80 (5.76)	2.60 (0.68)
Organic solvent content, Mg/yr (tons/yr)	3.64 (4.00)	3.88 (4.28)	4.16 (4.56)	0.52 (0.56)
Projected national discharge for the year 1985				
Total discharge flow, 10^6 liters/yr (10^6 gallons/yr)	708. (187.)	724. (191.)	740. (196.)	32. (9.)
Organic solvent content, Mg/yr (tons/yr)	135. (148.)	138. (152.)	141. (155.)	6. (7.)

*Basis:

1. Potential water discharge flow equal to steam usage at 4 Kg steam per Kg recovered solvent; water density at 1.0 Kg/liter (8.34 lb/gal)
2. Estimates of recovered solvent from Table 6-1 and Table 7-3
3. Discharged water contains an average 190 ppm organic solvent

water (less than about 5 ppm) as makeup feed water to the plant steam boiler, as described in Chapter 4 and used in development of model plants in Chapter 6.

Alternatively, the solvent laden condensate could be discharged to a conventional biological waste treatment system (e.g., activated sludge, trickle filter). At present, there are no Federal effluent regulations specifically for the printing industry. However, most State effluent regulations are at least as stringent as the Federal regulations for secondary treatment of municipal wastewaters.[21] These Federal regulations would require a minimum 85 percent removal of the organic solvent content in the discharged condensate and would allow only a maximum of 30 mg/L of five-day biochemical oxygen demand (BOD_5), as averaged over 30 days. BOD_5 is defined as the amount of oxygen required by the bacteria over a five day period to reduce most of the organic matter to water and carbon dioxide and provide new cell growth.

The BOD_5 of a waste water stream is normally measured as the difference in the dissolved oxygen content, determined from analyses of a sample of the wastewater both initially and after five days. However, the BOD_5 of a typical condensate stream containing 200 mg/L (200 ppm) of toluene solvent can be estimated by considering the following simplified general biological reaction:

$$\underset{\text{Toluene}}{1\ C_7H_8} + \underset{\text{Oxygen}}{9\ O_2} \xrightarrow{\text{Microorganisms}} \underset{\text{Carbon Dioxide}}{7\ CO_2} + \underset{\text{Water}}{4\ H_2O}$$

In addition, the BOD_5 is usually about 70 percent of the ultimate required oxygen to totally remove all of the organic matter.[22] Therefore, on a weight basis, the BOD_5 for the typical condensate effluent would be about 2.2 times the solvent concentration, or about 438 mg/L. The overall water pollution impacts from discharge of solvent containing condensate would be small. Under the 85 percent control option a large plant would discharge approximately 70 lb BOD_5/day which is an amount equivalent to a population of 350 people. The total nationwide incremental impact would be about 30,000 gallons/day with a BOD_5 concentration of 108 lb/day (540 people equivalent). The required removal efficiency is calculated to be about 93 percent to meet the 30 mg/L BOD_5 level. A secondary impact resulting from biological treatment of the waste water is the production of sludge. Sludge handling is discussed in the next section on solid waste impacts.

A second alternative would be treatment of the wastewater by carbon adsorption.[23] The use of activated carbon has been demonstrated to be one of the most efficient organic removal processes. The organic content in the effluent can be reduced to below one mg/L BOD_5 by activated carbon treatment.

Two other sources of water pollution resulting from carbon adsorption control systems are the plant cooling tower and steam boiler blowdowns. Dissolved organics and solids in these discharge streams represent only minor sources of pollution compared to the condensate stream. The cooling tower water and steam usages increases in direct proportion to the amount of recovered solvent. The respective blowdown rates would thus increase correspondingly. These two sources are controlled under State and local regulations. No attempt is made to quantify the estimated impacts of these two sources.

7.3 SOLID WASTE IMPACT

There are two potential direct sources of solid waste material resulting from VOC emission control by carbon adsorption/solvent recovery systems. The first direct source is the activated carbon used in the adsorber vessels. Estimates of the potential amount of waste activated carbon resulting from the model plants and industrywide projections through the year 1985 are presented in Table 7-5. As mentioned in Chapter 4, the activated carbon should not need to be replaced for at least five years for service in this industry. Thus, the actual solid waste impact would more than likely be much lower than estimated. Handling of the waste carbon should not pose any significant problems. The carbon can be sent back to the manufacturer for high temperature

TABLE 7-5. POTENTIAL SOLID WASTE IMPACTS FOR VOC EMISSION CONTROL ON MODEL PLANTS BY FIXED-BED CARBON ADSORPTION/SOLVENT RECOVERY SYSTEMS THROUGH THE YEAR 1985, MG (tons)*

Plants/facilities	Overall Solvent Recovery Efficiency			Incremental VOC Control
	75%	80%	85%	75% - 85%
Small plants	16.9 (18.6)	18.0 (19.8)	19.1 (21.1)	2.2 (2.5)
Large plants	33.7 (37.2)	36.0 (39.6)	38.2 (42.2)	4.5 (5.0)
Total 75 new presses[a]	632.8 (697.5)	675.0 (744.0)	717.2 (790.5)	84.4 (93.0)

*Basis:

1. Total activated carbon usage is estimated from --
    - a. 120 gallons/hr/press total solvent usage -- See Table 6-1;
    - b. 2 hour adsorption time per cycle;
    - c. 0.06 Kg solvent/Kg carbon adsorption capacity -- See Table 4-1; and
    - d. 0.742 Kg/liter (6.2 lbs/gallon) solvent density

2. Activated carbon replacement required only once every five years

[a] Projected total new presses through the year 1985 -- See Chapter 8.

regeneration. In addition, the carbon could be incinerated, supplying an excellent source of fuel energy. Also, disposal by landfilling is possible without any serious environmental problems.

The second direct source of solid waste is the SLA filters. These filters are usually made of fiberglass materials. Usage of the filters increases proportionately to the SLA flow rate. The amount of waste filters for control at the 80 to 85 percent levels would, thus, increase by about nine and 40 percent over that for baseline control, respectively. Some of the filters can be cleaned and reused. An estimate of the bulk quantities of waste filters is not attempted. The waste filters contain no harmful materials and can be disposed of commercially.

A potential secondary source of solid waste would result from the biological treatment of the waste water. Waste biological sludge is produced when excess microorganisms are removed from the treatment process to control the microorganism population. For the typical wastewater stream containing 200 mg/L (200 ppm) toluene solvent, the 93 percent BOD_5 removal would result in the production of about 0.35 Kg sludge per Kg of BOD_5 in the effluent.[24] The sludge handling requirements for model plants and industrywide projections for the year 1985 are presented in Table 7-6 for each regulatory alternative considered. The estimated solid waste impacts are calculated from the wastewater discharges presented in Table 7-4.

7.4 ENERGY IMPACT

The operation of carbon adsorption solvent recovery control systems require electrical energy and steam usage. The steam is used to regenerate the carbon beds and recover the solvent, at an assumed constant ratio of 4 Kg steam per Kg recovered solvent. The in-plant steam boilers are assumed to generate steam by fuel oil combustion half of the time and by natural gas combustion half the time. Heating values of 39.0 GJ/m^3 (140,000 Btu/gal) and 37.2 MJ/Nm^3 (1,000 Btu/SCF) were assumed for fuel oil and natural gas, respectively. An 80 percent thermal efficiency was assumed for each fuel usage. The electrical energy is mostly required

TABLE 7-6. POTENTIAL SECONDARY SOLID WASTE IMPACTS FOR BIOLOGICAL TREATMENT OF WASTEWATER DISCHARGED FROM CONTROL OF VOC EMISSIONS IN THE PUBLICATION ROTOGRAVURE PRINTING INDUSTRY USING FIXED-BED CARBON ADSORPTION/SOLVENT RECOVERY, Mg/Yr (Tons/Yr)*

	Overall Solvent Recovery Efficiency			Incremental VOC Control
Items	75%	80%	85%	75% - 85%
Small Model plants	1.6 (1.8)	1.8 (2.0)	2.0 (2.2)	0.4 (0.4)
Large Model plants	3.3 (3.6)	3.6 (4.0)	4.0 (4.4)	0.7 (0.8)
Projected industry-wide total for the year 1985	130 (143)	133 (147)	136 (150)	6 (7)

*Basis:

1. Estimates of wastewater discharges from Table 7-4.
2. Waste sludge production equal to 0.35 Kg sludge per Kg of BOD_5 in the effluent.
3. Sludge handling factor of 1.25 applied for inert allowance.
4. Effluent BOD_5 loading is about 2.2 times the organic solvent content, on a weight basis.

for operating the large SLA fans. Additional smaller amounts of electricity are required for the cooling tower pumps and fans, boiler support systems, and all emissions controls instrumentation. Total electrical consumption is estimated for 5,470 hours per year, which represents about 75 percent of scheduled press operating time. Total annual electrical usage is about 64.9 GJ per 1,000 m^3/hr (30,630 KWh per 1,000 CFM) of SLA, based on a rate of 5.6 KW/ 1,000 CFM of SLA.

The annual energy requirements for VOC control in a large model plant are presented in Table 7-7. Control of emissions at the 85 percent level would require about 18 percent more direct energy than at the 75 percent level. Steam usage accounts for about 86 percent of the total direct energy consumption at the 75 percent control level; whereas, steam represents about 83 percent of the total energy usage at the 85 percent control level, where more electrical energy is required for capture of fugitive vapors. However, there would be net energy savings associated with control at all three regulatory levels, when the fuel energy value (heat of conbustion) of the recovered solvent is considered. Control at the 85 percent level would thus provide about an 11 percent energy savings over control at the 75 percent level.

The projected energy usage for new source VOC control in the year 1985 is presented in Table 7-8. The estimate is scaled-up from the large model plant analysis, on an energy consumption per unit of recovered solvent basis. The industry's total direct energy consumption in the year 1985 for VOC emission controls at the 75 percent level would be about 2.6 million GJ (2.5 X 10^{12} Btu). The energy consumption would be increased by about an additional 3 to 9 percent for controlling new press emissions at the 80 and 85 percent levels, respectively.

However, there is a net national energy savings when the fuel energy value of the recovered solvent is considered. Nationwide energy consumption in the year 1985 would be actually decreased by about 5.6 million GJ (5.3 X 10^{12} Btu), with VOC emission controls and solvent recovery at the 75 percent level in this industry. These energy savings

TABLE 7-7. TOTAL ANNUAL ENERGY REQUIREMENTS OF VOC CONTROL BY CARBON ADSORPTION FOR LARGE MODEL PUBLICATION ROTOGRAVURE PLANTS

Energy Sources	Overall NSPS VOC Control Efficiency			Incremental
	75%	80%	85%	75%-85%
Direct Consumption				
No. 2 fuel oil, m^3 (10^5 Gals.)	768 (2.03)	821 (2.17)	870 (2.30)	102 (0.27)
Natural Gas, Mm^3 (10^7 Ft^3)	0.804 (2.84)	0.858 (3.03)	0.912 (3.22)	0.108 (0.38)
Total Fuel Value[a], GJ (10^{10} Btu)	60.018 (5.69)	63,953 (6.06)	67,921 (6.44)	7,903 (0.75)
Electric Power[b], GJ (10^6 KWH)	9,396 (2.61)	10,344 (2.87)	14,123 (3.92)	4,727 (1.31)
Total Energy, GJ (10^{10} Btu)	69,414 (6.58)	74,297 (7.04)	82,044 (7.78)	12,630 (1.20)
Recovered Solvent[c], Mg (Ton)	4,800 (5,290)	5,120 (5,640)	5,450 (5,990)	650 (700)
Total Energy Value[d], GJ (10^{10} Btu)	223,056 (21.2)	237,625 (22.6)	252,941 (24.0)	29,885 (2.8)
Net Energy Savings, GJ (10^{10} Btu)	153,642 (14.6)	163,328 (15.6)	170,897 (16.2)	17,255 (1.6)

[a] For steam generation requirements of 4 Kg steam per Kg recovered solvent.

[b] Operation of large SLA fans, cooling tower pumps and fans, boiler pumps and fans, and all emission controls instrumentation--64.9 GJ/yr per 1,000 m^3/hr of SLA (30,630 KWH per 1,000 ACFM of SLA).

[c] See Table 7-3.

[d] Heating value of toluene, xylene, paraffins mixed solvent at 46,470 J/g (20,000 Btu/lb).

TABLE 7-8. PROJECTED 1985 TOTAL ENERGY REQUIREMENTS OF VOC CONTROL BY CARBON ADSORPTION FOR THE PUBLICATION ROTOGRAVURE INDUSTRY

Energy Sources	Overall NSPS VOC Control Efficiency			Incremental
	75%	80%	85%	75%-85%
Direct Consumption[a], 10^6 GJ (10^{12} Btu)	2.56 (2.42)	2.63 (2.49)	2.78 (2.64)	0.22 (0.22)
Recovered Solvent[b], Mg (tons)	177,110 (194,820)	181,050 (199,160)	184,990 (230,490)	7,880 (8,670)
Recovered Energy[c], 10^6 GJ (10^{12} Btu)	8.23 (7.81)	8.40 (7.98)	8.59 (8.15)	0.36 (0.34)
Net Energy Savings, 10^6 GJ (10^{12} Btu)	5.67 (5.39)	5.77 (5.49)	5.81 (5.51)	0.14 (0.12)

[a] Scaled-up from large model plant ratio of total direct energy consumption per unit of recovered solvent--See Table 7-7.

[b] See Table 7-3.

[c] See Table 7-7 for solvent heating value.

would be further increased by about an additional 2 to 3 percent for controlling new press emissions at the 80 and 85 percent levels, respectively. Solvent supplies are closely related to gasoline and other fuel supplies, which will become less available and more expensive in the future. Toluene, and other solvent components, are used in automobile fuels. The available energy value of the solvents used in rotogravure printing must be considered. Therefore, the highest level of control of VOC emissions provides a very favorable national energy impact, as well as air pollution impact.

7.5 NOISE POLLUTION IMPACT

The only significant source of noise would be from the large SLA fans. However, these are normally installed in an enclosed housing and should not affect the surrounding environment. The operators may need to wear conventional ear protection for work very close to the fans for extended periods. No other significant, detrimental noise impact is expected from the control of VOC emissions from the publication rotogravure industry.

7.6 SUMMARY

Other than the fuels required for steam and electricity generation, and the materials required for the construction of the system, there is no apparent irreversible or irretrievable commitment of resources associated with the construction or operation of the control systems. Many of the construction materials and the land itself could be reclaimed. The installation of VOC air pollution control systems in this industry do not produce any significant air, water, or land pollution side effect problems. In addition, recovery of the solvent is energy efficient. The economic impact analysis presented in Chapter 8 shows that solvent recovery provides positive economic impacts, as well.

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8. ECONOMIC IMPACT

8.1 INDUSTRY CHARACTERIZATION

8.1.1 General Profile

The graphic arts industry, which includes all printing, publishing, and allied industries is characterized by the U.S. Department of Commerce as a division of "Standard Industrial Classification" (SIC) 27. The total product value from this group has increased from about $43 billion in 1976 to about $53 billion in 1978.[1] Commercial printing, SIC 2751-2-4 is a subclassification of this group. Printing receipts have increased from over $13 billion in 1976 to over $16 billion in 1978. Gravure printing is a subclassification of commercial printing and is listed as SIC 2754, commercial printing-gravure. Gravure publication printing is listed as subclassification of commercial printing, and is denoted as SIC 27541. However, for the purposes of this study, gravure publication printing is defined as including SIC 27541 and SIC 27543 (gravure advertising printing).

The publication rotogravure printing industry represents the largest of the three sectors involved in gravure printing. Packaging and specialties printing are the two other gravure sectors, but these are not considered in this study. There are many differences in the solvent, substrate, ink, and equipment used in these three gravure sectors.

An industry survey[2] rated the value of gravure publication shipments at over $2.1 billion, and over 37 percent of the total gravure shipment value in 1976. The major publication gravure product areas fall in the following categories (dollar value percentage):

• newspaper supplements and preprinted inserts	- 58 percent
• catalogs (all types)	- 19 percent
• magazines	- 18 percent
• advertising printing	- 5 percent

The distribution of these gravure publications is extensive. In 1976, over 183 million newspaper supplements and preprinted inserts were distributed weekly. In addition, over 180 million magazines every month were printed either entirely or partly by gravure. Despite this large circulation, this volume of printed material is produced in fewer than 30 plants nationwide.

There were 27 gravure publication printing plants in operation as of July, 1979. These plants are distributed among 15 states. Illinois has the greatest concentration, with six plants (three in Chicago alone), which contain approximately one-third of the total number of production presses in the industry. Ohio and California each have three publication gravure operations, and Tennessee, Kentucky, and New York each have two. The remaining nine plants are scattered among as many states, all but two of which are east of the Mississippi. An additional plant is currently under construction in North Carolina. Table 8-1 is a geographic distribution of the gravure publication plants in this country.

Very little activity occurs in the import/export market for printed products. In the printing and publishing industry (SIC 27), combined imports and exports have recently been somewhat in excess of $1 billion annually (about 2 percent of the 1978 market value). Books and periodicals account for roughly three-fourths of exports and two-thirds of imports. Exports typically exceed imports in a ratio of two to one. This ratio, and the same general volume of international trading are expected to continue into the early 1980's. Canada, the United Kingdom, Australia and Japan are the major export markets.[1] The ratio of exports plus imports to total value of shipments is similar in the commercial printing portion of the industry (SIC 2751-2-4) and is expected to remain so in the next few years.[3] Exports and imports are thus not a particularly significant component of the markets for publication gravure products.

The 27 gravure publication plants (soon to be 28) are operated by 17 companies. As Table 8-2 shows, a number of these operating companies are privately owned, and others are subsidiaries of larger corporations. Three of the owners, Charter, City Investing, and Mobil Oil, are highly

TABLE 8-1. GEOGRAPHIC DISTRIBUTION OF GRAVURE PUBLICATION PRINTING PLANTS AS OF JULY, 1979[a]

Illinois	6
California	3
Ohio	3
Kentucky	2
New York	2
Tennessee	2
Colorado	1
Indiana	1
Iowa	1
Maryland	1
Mississippi	1
Pennsylvania	1
Rhode Island	1
Texas	1
Virginia	1
TOTAL	27

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[a] Takes into account the 1978 closing of Triangle Publications in Philadelphia and the planned 1979 opening of the Brown Printing Company plant in Bowling Green, Kentucky.

TABLE 8-2. OWNERSHIP OF GRAVURE PUBLICATION PRINTING ESTABLISHMENTS

Owner	Operating company[a]	Establishment
Arcata Corporation		Arcata Graphics San Jose Graphics
Art Gravure Corp.[b]		Art Gravure Corp.
Bemis[b]	Brown Printing Co., Inc.	Brown Printing, Bowling Green
The Charter Company	Dayton Press, Inc.	Dayton Press
City Investing Company	World Color Press	Salem Gravure
The Denver Post, Inc.		The Denver Post Gravure West
The George Banta Company		Springfield Gravure
Macmillan, Inc.	Alco-Gravure, Inc.	Alco Gravure, Chicago Alco Gravure, Glen Burnie Alco Gravure, Memphis Alco Gravure, Los Angeles
Meredith Corporation		Meredith
Meredith Corp. and Burda GmbH	Meredith/Burda, Inc.	Meredith/Burda
Mobil Oil Corp.	W. F. Hall	Chicago Rotoprint Co. Hall of Miss. Printing Company
New York News, Inc.[b]		Newsprint Gravure Plant
Parade Publications, Inc.[b]		Diversified Printing Corp.
Providence Journal Co.[b]		Providence Gravure, Inc. Texas Color Printers

Continued

TABLE 8-2. Continued

Owner	Operating company[a]	Establishment
R. R. Donnelley and Sons		R. R. Donnelley, Chicago R. R. Donnelley, Warsaw R. R. Donnelley, Mattoon R. R. Donnelley, Gallatin
Standard Gravure Corp.		Standard Gravure Corp.
Western Publishing Company		Kable Printing Company

[a] Where different from owner

[b] Privately held company

diversified concerns. Most of the other owners are involved in one or more aspects of printing or publishing in addition to gravure publications.

8.1.2 Trends

8.1.2.1 Product Demand. The printing and publishing industry serves a wide range of educational, cultural, business, and informational needs. Strong economic growth, a better-educated population, and higher personal incomes are significant factors affecting the demand for printed products. Equitable postal rates, and an expanding economy have been major factors in a continuing strong growth pattern for the printing industry. Consid-siderable competition in the advertising market is generated by the broadcasting industry, and a reduction in advertising expenditures is more likely to affect the printing industry, than it would the broadcasting industry.[4]

Gravure publication printing has experienced increased growth in the printing and publishing industry. The GTA-GAMIS survey[5] reported that gravure's contribution to the total printing and publishing industry will increase from 14 percent in 1977, to an estimated 16 percent in 1980, and then to 25 percent by 1990. These trends are largely the result of technological advances in the presses and in cylinder preparation. Cylinder preparation is a costly and time-consuming process, preventing gravure from competing with the other processes on short runs. However, automation and other changes in this pre-press phase of gravure printing have lowered the minimum run length at which gravure can compete with lithography from 1 million to 500,000 or even 250,000[6] copies in some cases. This significant improvement represents the gradual elimination of gravure's major competitive disadvantage with other printing processes.

The process has a number of distinct advantages. It is better able to handle long runs. It is the only process that can vary the thickness of the ink layer on the page and can thereby reproduce art work. It can better handle lesser grades and lighter weights of paper, including uncoated stock, and can operate with less waste, all very meaningful in the face of paper shortages and rising postal rates and paper costs.[7] Publication gravure printing is in an especially good position to take advantage of rapidly rising demand from publishers of newspaper inserts and magazines. The market for publication gravure printing can be expected to grow rather rapidly in the foreseeable future due to growth in demand for printed products, and gravure's improving competitive advantage with respect to letterpress and offset lithography.

8.1.2.2 Factors Affecting Supply. There are a number of constraints on the ability of the publication gravure industry to take full advantage of the increasing demand. Limited availability of new equipment, age of existing equipment, present high equipment utilization rates, and projected shortages of materials all contribute to supply constraints.

There are three principal manufacturers of publication gravure presses: Albert-Frankenthal AG (Germany), Motter Printing Press Company (York, Pennsylvania) and Officine Meccaniche Giovanni Cerutti S.p.A. (Italy). Motter is able to build six presses per year and has a two-year backlog. Albert-Frankenthal and Cerutti each have the capacity for about ten presses annually, but at least half of their production is committed to filling European orders at present. Cerutti is considering opening an American assembly plant, but it would at first produce only packaging gravure presses.[8] Consequently, it appears that between 10 and 15 presses per year is the most that could be expected for the U.S. market over the next five years. Some of these new presses will be replacements for existing equipment. Few presses can still do top quality work after 15 years, and the 1976-1977 GTA-GAMIS Survey showed that approximately one-fourth of those in operation exceed that age, while about one-half are between five and 15 years old.[9] Some of these older presses will be overhauled, but others will require replacement.

Commerce Department statistics show that commercial printing utilization rates have been 80 to 81 percent of practical capacity between 1975 and 1977.[10] The practical capacity is defined as the greatest level of output a plant can achieve, considering a realistic work pattern, normal product mix, operable machinery, and reasonable time for maintenance. Trade association sources confirm that the present capacity in publication gravure printing is utilized on the average at 80 to 85 percent of practical capacity. However, seasonal work catalogs and holiday advertising results in virtually no excess capacity for 70 percent of the time.[11] This observation seems consistent with another Commerce Department finding that commercial printers operated at 96 and 95 percent of preferred capacity in 1976 and 1977, respectively.[10] The preferred capacity is defined as the production level in which the manufacturer would prefer not to exceed due to cost and other considerations. It is not likely that anything more than a 10 percent increase in output could be obtained from existing capacity; five percent would be a more reasonable expectation.

There is currently a paper shortage, and it is likely that this shortage will persist into the early 1980's. Estimates of the shortfall vary, but in 1979, new production capacity for printing grades of paper is estimated to be up 2.5 percent, while the lowest estimate of real growth for commercial printing is 3 percent.[12] Estimates indicate a demand for gravure grades of paper will increase 4 percent annually, while the paper production will only increase at 2.5 percent.[13] The costs of whatever gravure paper is available are expected to increase by 10 percent in 1979 alone.[12] However, a shortage of paper, particularly of the higher or heavier grades, may improve gravure's competitive advantages over other printing processes. Gravure presses waste less and can operate with poorer and lighter grades of paper. A serious shortage would of course affect all printing methods adversely, even if gravure were comparatively less severely restricted in output.

Many of the ink components are petroleum derivatives, and consequently ink costs are increasing sharply and will likely continue to do so. Moreover, many of the solvent constituents, especially toluene, are also used as gasoline additives. Their prices are therefore established in a market in which printers are a small customer with virtually no ability to affect prices. A typical gravure publication solvent mix which sold for 65 cents per gallon in January of 1979 was priced at 80 cents on July 1, 1979, and is expected to rise to a least 90 cents by the end of 1979.[14,15]

In summary, any publication gravure expansion will be limited by a number of short-term constraints, some of which are very strong. The new sources which come into being in this rapidly growing industry are likely to be influenced by these supply factors.

8.1.2.3 Industry Growth Projections. Historically, the real growth of the commercial printing industry has closely followed real growth in gross national product (GNP). Considering an annual average of 3 percent real increase in GNP for the next five years, a 3 percent annual increase in the total value of output from commercial printers (in constant dollars) is expected. To this can be applied the publication gravure market share with some rate of annual increase, to arrive at a set of growth projections. Since estimates of the rate of increase of the market share vary, four alternative projections were determined and are presented in Table 8-3. The initial (1976) market share of 16 percent was calculated using industry survey statistics for publication gravure and U.S. Department of Commerce records for commercial printing.[2,3] The 1976 dollar value for commercial printing was $13,355,000,000 while the publication rotogravure printing value was $2,129,200,000. The base year chosen for projections is 1976, the year for which the most complete data were available. The four alternative projections (I, II, III, and IV) were determined by assuming the following information:

Projection I - Constant 16 percent market share (3 percent annual real growth)

Projection II - GTA estimate of 5 to 6 percent real growth annually to 1985 (5.5 percent annual real growth)

Projection III - Market share increasing 1 percent per year, from 16 to 25 percent (plus 3 percent annual real growth)

Projection IV - Market share increasing 1.5 percent per year, from 16 to 29.5 percent (plus 3 percent annual real growth)

These four projections are graphically illustrated in Figure 8-1. Projection I, an annual real growth rate of 3 percent is clearly conservative for this expanding industry. Any of the other three projections appear possible, considering only the increased demand for gravure publication products. However, the restrictions on supply, in particular those imposed by the capacities of gravure press manufacturers, must be introduced into the growth projection process to determine which of curves II, III, and IV are reasonably attainable.

TABLE 8-3. PUBLICATION ROTOGRAVURE PRINTING INDUSTRY TOTAL OUTPUT[a] AT TYPICAL 81% UTILIZATION CAPACITY UNDER FOUR ALTERNATIVE PROJECTIONS

Projection	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
I	2,129	2,193	2,259	2,327	2,396	2,468	2,542	2,619	2,697	2,778
II	2,129	2,246	2,370	2,500	2,638	2,783	2,936	3,097	3,268	3,447
III	2,129	2,339	2,550	2,773	3,006	3,251	3,508	3,778	4,060	4,356
IV	2,129	2,407	2,692	2,992	3,307	3,638	3,987	4,352	4,737	5,140

[a] Output is in millions of 1976 dollars.

I - 3% Real Growth

II - 5.5% Real Growth

III - 3% Real Growth plus 1% annual increases in Market share.

IV - 3% Real Growth plus 1.5% annual increase in Market share.

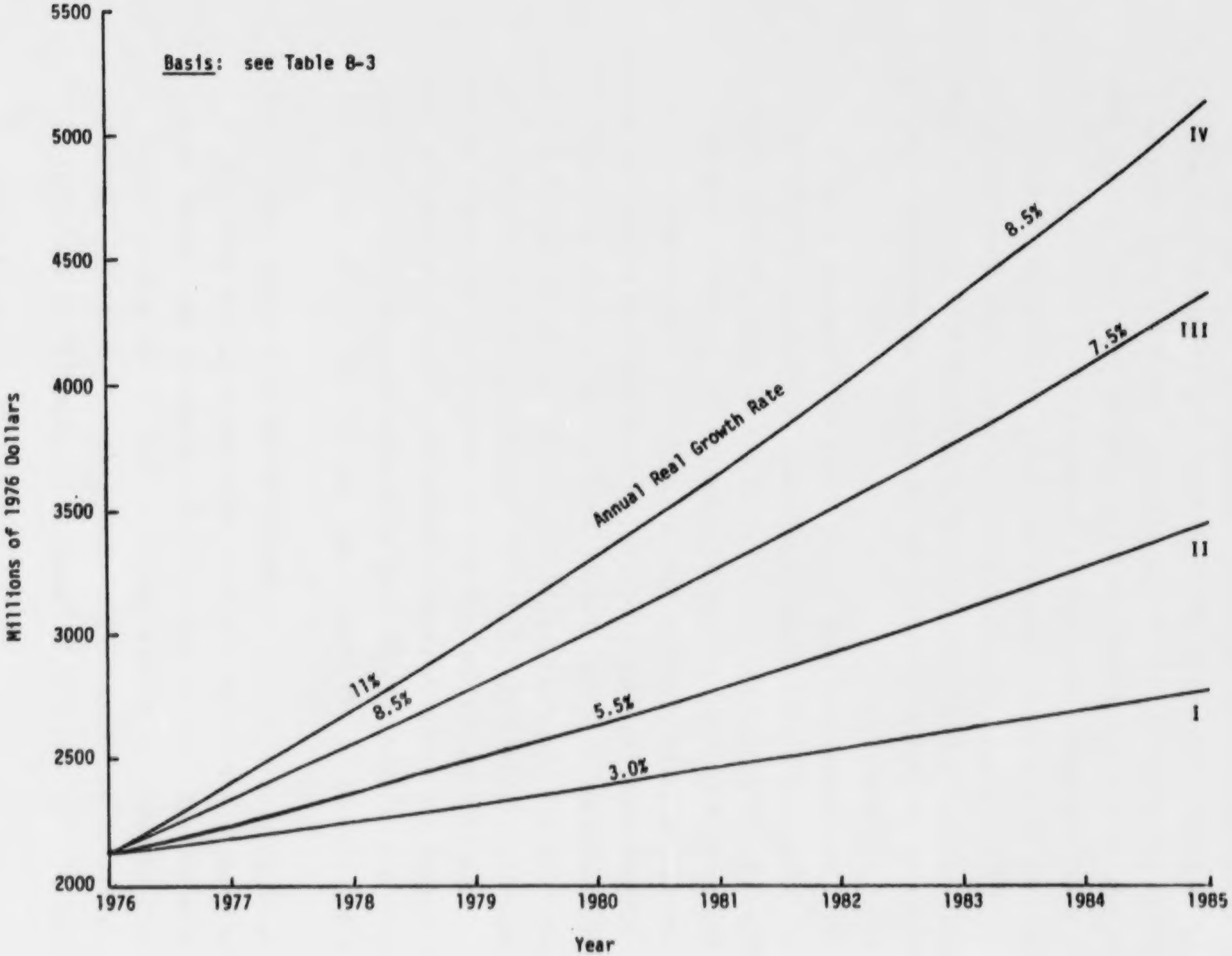

Figure 8-1. Alternative growth projections for the publication rotogravure printing industry at typical 81 percent utilization capacity.

The annual dollar value product output of a gravure press cannot be accurately determined due to the mix of products typically produced and the variety of sizes and weights of paper used. An annual dollar-value product output per press factor of approximately $15.8 million was estimated using the 1976 total output value, $2,129,200,000, and the fact that there were about 135 production presses in operation at that time.[2,16] Since 81 percent of practical capacity was being utilized by commercial printers in 1976, a single gravure publication press would then theoretically produce about $19.5 million worth of product at full practical capacity. Production at preferred capacity* (84 percent of practical capacity) would be about $16.4 million.

The press manufacturers, even in 1979, can only produce 10 to 15 presses for the United States market each year. Therefore the gravure publication capacity (based on 1976 dollars) can be expanded at an annual rate of $158 to $237 million at typical capacity (81 percent), $164 to $246 million at preferred capacity (84 percent), and $195 to $293 million at full practical capacity (100 percent). Figure 8-2 illustrates the growth constraints associated with the production of 10 new presses per year. These constraints are superimposed on the project growth curves (from Figure 8-1) for capacity utilizations of 81, 84, and 100 percent of full practical capacity. These constraints include the new press capacity as well as the additional output available through increased utilization of existing capacity. Figure 8-3 illustrates the same relationship as Figure 8-2, except that the production of 15 new presses per year is used rather than 10 per year.

The rates of possible capacity expansion may be somewhat understated, because new presses are faster and more efficient than old ones. It appears, nevertheless, that growth curve IV, an annual real growth rate of about 10.5 percent, is no more realistic than is the probability of continued operation at 100 percent of full practical capacity. Therefore the remainder of this analysis is based on the expectation that real

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*Operation during 1976 was 96 percent of preferred capacity,[17] which was also equivalent to 81 percent of practical capacity. Therefore the preferred capacity was 84 percent of the practical capacity.

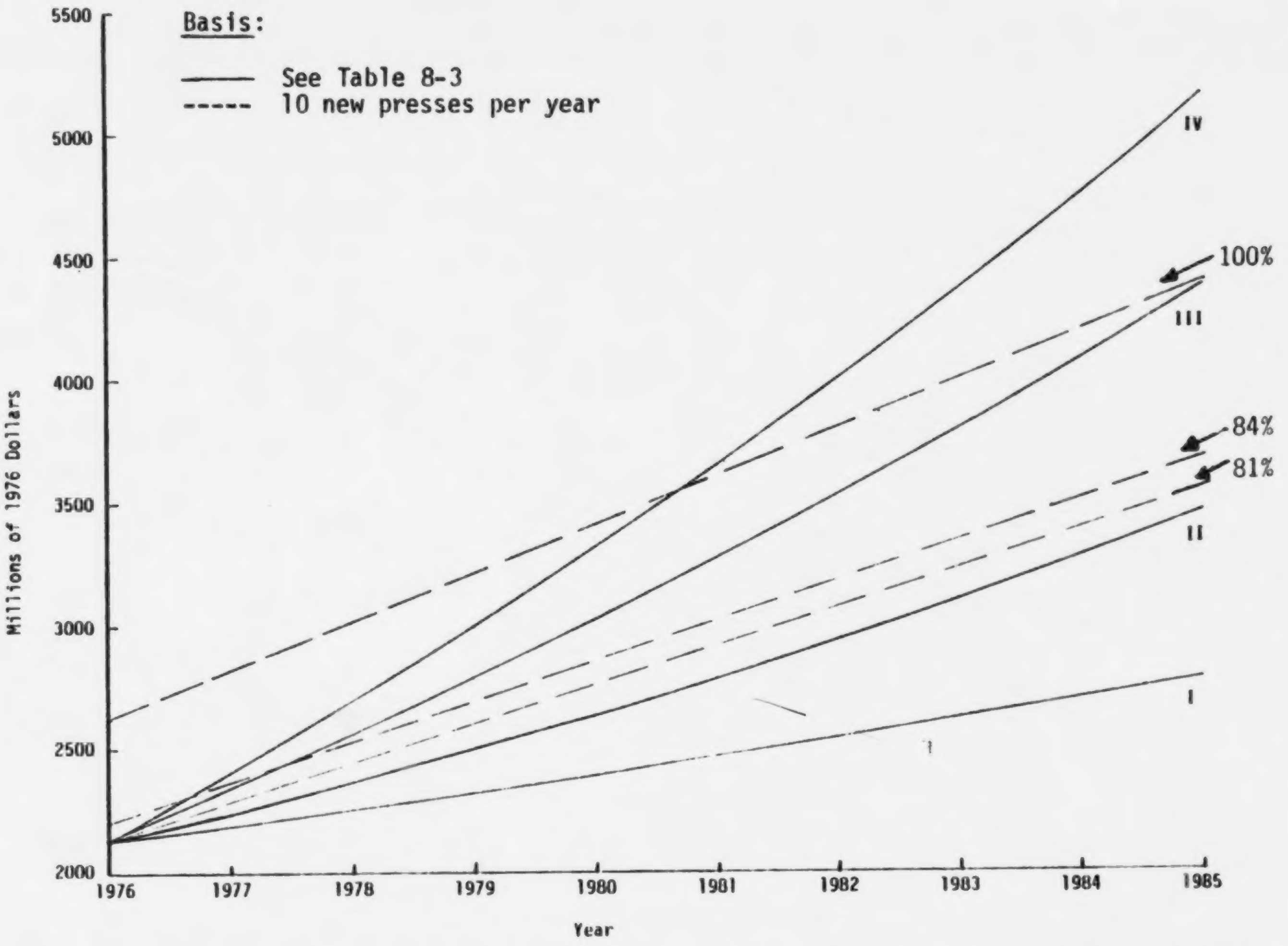

Figure 8-2. Alternative growth estimates for the publication rotogravure printing industry with constraint of 10 new presses per year superimposed at utilization capacities of 81%, 84%, and 100%.

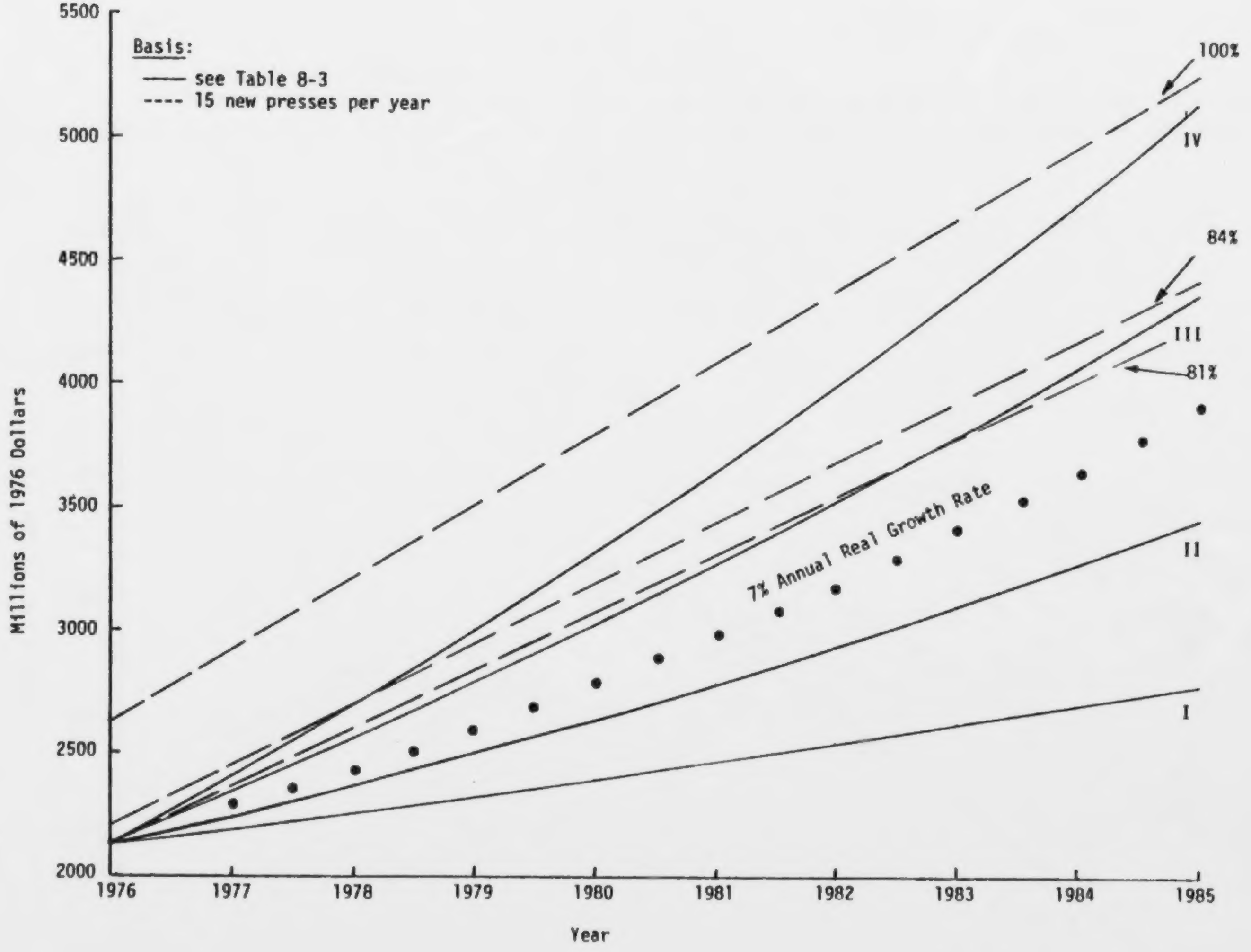

Figure 8-3. Alternative growth estimates for the publication rotogravure printing industry with constraint of 15 new presses per year superimposed at utilization capacities of 81 percent, 84 percent, and 100 percent.

expansion will occur within the envelope bounded by curves II and III, at a nominal rate of about 7 percent per year.

8.1.2.4 Affected Facilities. Modifications and reconstruction of existing rotogravure printing presses are described in Chapter 5. A number of reasons account for the low probability that any "affected facilities" will be created through modification or reconstruction. While older presses may operate properly for many years under proper maintenance, recent and continuing improvements in peripheral equipment and automation make new equipment more desirable.[11] Older presses are often retained for back-up or peak demand capacity, when new equipment is purchased. Consequently, reconstruction and modification is not considered a significant generator of "affected facilities".

The ages of existing equipment and the projected growth in demand are such that the maximum output of the publication gravure press manufacturers will probably be utilized between 1979 and 1985. To meet the projected seven percent annual real growth rate, the industry appears to be demanding more new press capacity than immediately needed. This industry seems to be favoring the installation of an excess of new presses utilized at a lower rate, rather than operating with fewer presses at increased utilization rates. Thus, assuming a maximum 15 presses per year can be manufactured, approximately 75 individual new presses over the five-year period of analysis (1981-1985) are expected. Most of these new presses will be devoted to expansion of existing operations; however, some existing presses will be replaced. About 25 percent of the new presses are expected to go into new grass roots plants. The number of production presses will, therefore, total about 250 by the year 1985.

To achieve the same seven percent growth rate with new, model plant type presses, only about 45 new presses, utilized at the 81 percent rate, would be required. This is because modern presses are faster and more efficient than older presses. The model plant presses have the capacity to operate at speeds of about 2000 ft/min (see Table 6-1) compared to only 1200 to 1500 ft/min for older, existing presses (see Chapter 3). However, the printing of some type products may require lower press speeds and may result in lower press utilization rates. The result of these operating conditions would increase the required number of model plant type presses.

If 75 new model plant type presses were used at an 81 percent utilization rate with all existing presses, the industry's potential annual real growth rate from 1981 through 1985 could be as high as eight to nine percent. However, the higher speed new presses will allow a lower utilization rate than older presses to meet customer demands. This will decrease the required number of hours that operators will have to be paid to print an equivalent amount of product. The projected seven percent growth rate is, therefore, conservative, but reasonable when decreased press utilization and possible requirements for lower press speeds combined with replacement of some old presses by new presses is considered.

Since approximately 75 percent of expected expansions will occur at existing operations, most new plants in this industry will be located in the 15 states where publication gravure plants are presently concentrated. All but four of them are east of the Mississippi, and little West Coast growth is expected.[11]

The often-mentioned tendency for new manufacturing industries to locate in the southern states to take advantage of less-expensive labor is not particularly significant for publication gravure and is becoming less so for two reasons. First, the industry's primary concern in the labor market is to obtain the highly skilled employees it needs, and they are in short supply. As equipment becomes still more sophisticated, the need for well-trained personnel will become even more significant. Second, the cost of shipping paper continues to rise, and most of it comes from Canada.[8] Consequently, although two of the newest plants will be in Kentucky and South Carolina, this does not necessarily signal a shift of the center of gravure printing to the south. It is likely that most new plants will be located in the northeastern quadrant of the United States since the raw material supplies such as paper and ink are already well established in this area.

There is no clear trend which can be used to predict the sizes of new publication gravure plants in terms of the two-press or four-press model plants postulated for this analysis. The most recent, new grass roots plant opened is a one-press operation in Bowling Green, Kentucky. However, another company has a four-press plant under construction in Spartanburg, South Carolina, scheduled for a 1980 opening. Another company has ordered four presses for expansion, while still another has ordered six for use in a single plant.[8] Consequently, the analyses presented in sections 8.4 and 8.5 considers the impacts associated with a mixture of model plant sizes. This mixture is an estimation of the expected future structure of this industry.

8.2 COST ANALYSIS OF REGULATORY ALTERNATIVES

Three regulatory alternatives are presented in Chapter 6. These alternatives call for an overall volatile organic compound (VOC) reduction of 75, 80, or 85 percent. The baseline, 75 percent, level of control corresponds to the anticipated State Implementation Plan (SIP) regulations. This is based on the Control Techniques Guideline[18] (CTG) document for this industry. A 75 percent VOC reduction is readily attainable on older gravure publication printing presses using conventional emission control technology. In fact, about 70 percent of the gravure publication plants currently have emission control systems which meet or exceed this CTG recommendation.

An intermediate 80 percent level of control is attainable using conventional emission control techniques on new presses. The new presses provide for better containment of the solvent vapors. This helps reduce fugitive vapor losses without any additional emission control equipment.

The highest control level considered at 85 percent, requires a significant effort to contain and treat fugitive vapors. One possible technique utilizing a proven method for capturing fugitive vapors is presented in Chapters 4 and 6. This technique is based on an existing plant which was tested by the EPA.

Each regulatory alternative is applied in conjunction with two plant sizes. A total of six model plants are used to describe the various configurations for new plants. Specific information about each model plant is presented in Chapter 6 (Table 6-1). A cost analysis is presented in this chapter for each emission control system used in the six model plants. The installed capital cost, operating cost, annualized cost, and cost effectiveness for each emission control system is analyzed for each model plant. A discussion concerning modified or reconstructed facilities is also presented.

8.2.1 New Facilities

The model plant analysis applies to six new plants. Two plant sizes are used to describe predicted new future plant configurations. Each plant contains one proof press and either two or four production presses. Only one control technology, fixed-bed carbon adsorption, is examined in this study. The costs presented in this section are order-of-magnitude type estimates based on plant experience and vendor quotations. The margin of error in the absolute costs is ±30 percent. The results presented herein are intended to be used as a comparative basis to examine the relative economics which may face a printer if a regulation goes into effect.

8.2.1.1 Capital Costs. The capital costs associated with the implementation of a fixed-bed carbon adsorption system are based on combined information from the printing industry [19,20,21,22,23,24,25,26] and also from equipment vendors.[27,28,29,30,31] The industry cost data obtained tended to be slightly higher than that supplied by equipment vendors. Detailed industry data is likely to be a better estimate of the actual costs incurred since this information also includes outside battery limits costs. Consequently, the cost analysis is based more heavily on past, detailed, industrial experience, rather than vendor quotations.

A carbon adsorption, solvent recovery system is usually purchased as a series of prefabricated equipment components. The purchased equipment price depends greatly on the SLA capacity, the instrumentation, and the materials of construction. The carbon adsorption systems analyzed in this study are all equipped with the same instrumentation options which are considered necessary for sustained high efficiency operation. The expected operating adsorber efficiency for these systems is 95 percent. This high efficiency is achieved by using moderately thick (0.75-1.0 meters) adsorption beds, and hydrocarbon vapor breakthrough analyzers. The analyzers are equipped with a backup timer override system which limits prolonged high outlet vapor concentrations if analyzer problems occur.

The purchased and installed capital costs of the carbon adsorption, solvent recovery systems used in the model plants are presented in Table 8-4. These costs do not include any facilities for the printing presses, or the presses themselves. These other costs are discussed in Sections 8.4 and 8.5. When necessary, the solvent recovery/emission control system costs were scaled to match the model plant sizes by employing the 0.6 power-law estimating equation. The equipment design sizes chosen for the model plant cases allow for the additional SLA flow from the proof presses. The "Chemical Engineering Plant Cost Index" was used to escalate all costs to first quarter (March) 1979 dollars.

Field assembly includes steam piping, electrical connections for recorders, gauges and instruments, and all insulation. The costs of mounting equipment and vessels on supports and/or foundations is also included. The cost of painting, as needed to prevent corrosion from the weather, is included as well. Field assembly expenses are estimated to be 25 percent of the purchased cost of equipment based on industry data.

Process buildings for the boiler, solvent recovery equipment, and the instrumentation are required to provide weather protection. No special or unusual circumstances are foreseen. The cost is estimated to be 20 percent of the purchased equipment cost.

The boiler cost, as presented, accounts for an entire steam generation plant. Sufficient excess steam capacity is provided. A steam to solvent ratio of 4.0 to 1 is assumed in the sizing of the boilers. The small model

TABLE 8-4. INSTALLED CAPITAL COST OF VOC CONTROL BY CARBON ADSORPTION[a] FOR GRAVURE PUBLICATION PRINTING PLANTS

Plant size	Small	Small	Small	Large	Large	Large
Overall V.O.C. control efficiency, %	75	80	85	75	80	85
Carbon adsorption system capacity (solvent laden air flow rate)						
Total production press flow rate; m³/hr (ACFM)	72,450 (42,640)	79,690 (46,900)	108,680 (63,960)	144,910 (85,280)	159,400 (93,810)	217,380 (127,930)
Proof press flow rate; m³/hr (ACFM)	18,110 (10,660)	18,110 (10,660)	18,110 (10,660)	18,110 (10,660)	18,110 (10,660)	18,110 (10,660)
Total solvent laden air flow rate; m³/hr (ACFM)	90,560 (53,300)	97,800 (57,560)	126,790 (74,620)	163,020 (95,940)	177,510 (104,470)	235,490 (138,590)
Purchased cost of solvent recovery equipment	$ 655,000	$ 695,000	$ 860,000	$1,050,000	$1,150,000	$1,265,000
Field assembly and utility tie-in (25% of purchased cost)	164,000	174,000	215,000	263,000	288,000	316,000
Process building (including foundations) for boiler, solvent recovery plant, and instruments (20% of purchased cost)	131,000	139,000	172,000	210,000	230,000	253,000
Support facilities: Boiler (installed) Cooling tower (installed)	135,000 27,000	135,000 27,000	135,000 27,000	145,000 42,000	145,000 42,000	145,000 42,000
Ductwork: Fugitive capture hoods and ducts Dryer exhaust ducts	- 50,000	- 52,000	126,000 55,000	- 92,000	- 98,000	252,000 103,000
Direct Costs	$1,162,000	$1,222,000	$1,590,000	$1,802,000	$1,953,000	$2,376,000
Start up (2.5% of direct costs)	29,000	31,000	40,000	45,000	49,000	59,000
Subtotal	$1,191,000	$1,253,000	$1,630,000	$1,847,000	$2,002,000	$2,435,000
Contingency costs (10% of subtotal)	119,000	125,000	163,000	185,000	200,000	244,000
Installed capital cost	$1,310,000	$1,378,000	$1,793,000	$2,032,000	$2,202,000	$2,679,000

[a] First quarter 1979 dollars

plants require one 24.7 Gj/hr (700 hp) boiler, while a 28.3 Gj/hr (800 hp) boiler will supply the large model plants. Boiler costs are determined from data given by various printers. They include the installed cost of the boiler, piping and general support facilities (e.g. water treatment).

Cooling tower costs are determined from one vendor quote of the purchased cost, supplemented by information from printers.[32] The costs, as presented, include the purchase price of a prefabricated, roof-mounted system. The cooling tower capacity is sized on the basis that an average of about 3 gallons of cooling tower water with a 23 C° (40 F°) temperature rise are required to cool and condense each pound of steam used in the carbon adsorption system.[27] The cooling towers for the small model plants are one-cell units whereas the large model plants use two-cell units. In both cases the cooling towers are sized to provide adequate excess capacity under all weather conditions.

Fugitive vapors must be captured and treated to achieve an 85 percent overall VOC reduction. The cost estimates for the 85 percent control levels in Table 8-4 are based on construction of a hood enclosure over each press to capture fugitive vapors.[22] The hoods are connected to a common duct running over the entire press. However, an extensive array of fume collection nozzles and ducts could be substituted with similar results. In either case, floor sweeps will also be required as usual to prevent hazardous fume concentrations during extended shutdown periods. The cost of the floor sweeps is not included in these estimates, since they represent a standard pressroom safety system. Fugitive vapor capture systems are only required on the 85 percent VOC reduction cases.

All of the model plant cases require ductwork to carry the SLA from the presses to the carbon adsorption units. Each production press will require about 45 meters (150 feet) of header, 0.9 meters (3 feet) in diameter. Each proof press requires 45 meters (150 feet) of header, 0.8 meters (2.5 feet) in diameter. The headers tie into a main duct which is about 90 meters (300 feet) long. The diameter of the main duct depends on the size of the printing facility. The cost estimate information for ductwork was obtained from contractors.[33,34,35]

Start up expenses are estimated at 2.5 percent of the direct costs. Initial performance testing is included in this figure. Contingency costs are estimated at 10 percent of the sum of the direct costs plus the start up expenses. This item is to allow for inclement weather during construction, labor disputes, small design changes, and other unexpected expenses.

Land requirements vary with the size of the individual carbon adsorption units. Estimates for land costs have not been included due to the uncertain nature of this expense. The land can also be reclaimed at a later date. The actual land requirement ranges from about 400-1000 m^2 (0.1-0.25 acres).

8.2.1.2 Annualized Costs and Cost Effectiveness. The annualized costs are composed of the sum of the annual operating costs and the annual capital charges minus the solvent recovery credit. The bases used in computing the annualized costs are presented in Table 8-5. Many of these items are dependent on location. Nevertheless, an effort has been made to use the figures which are representative of the entire gravure publication printing industry. A detailed breakdown of the annual operating costs for the six model plants is presented in Table 8-6. These costs reflect operating expenses for the carbon adsorption, solvent recovery systems.

An average of four kilograms of steam are required to recover a kilogram of solvent. For the purposes of this study, it is estimated that steam is produced 50 percent of the time by natural gas, and 50 percent of the time by No. 2 fuel oil. Natural gas costs are estimated at about \$106/1000 m^3 (\$3/1000 ft^3). No. 2 fuel oil costs are estimated at about \$0.132/liter (\$0.50/gallon). For a 50/50 fuel mix, the average cost per 1000 kilograms of produced steam is \$9.02/Mg (\$4.10/1000 lb steam). The total steam cost is therefore \$0.036/kg recovered solvent (\$0.0164/lb recovered solvent).

Electricity in a carbon adsorption plant is primarily required to operate fans for moving the SLA. The national average cost of electricity (in early 1979) was \$0.0277/kWhr.[36] However, the gravure industry-wide

TABLE 8-5. BASES FOR ANNUALIZED COST ESTIMATES

Description	Unit cost	Basis for costs and other comments
Annualized costs for new installation	One year	Commencing early (March) 1979
Average press operating time	4740 hr/yr	65% of scheduled operating time
Average solvent recovery plant operating time	5470 hr/yr	75% of scheduled operating time
Utilities		
Electricity	\$8.89/GJ (\$0.032/kWh)	
Steam	\$9.02/Mg (\$4.10/10^3 lb)	50% operation with No. 2 fuel oil at \$0.50/gal 50% operation with natural gas at \$3.00/1000 ft^3
Water	\$0.198/m^3 (\$0.75/1000 gal)	
Operating labor	12.00/hr	Includes fringes
Maintenance		
Labor	13.20/hr	Hourly rate at 10% premium over operating labor
Carbon replacement cost	2% of capital cost	Carbon life at 5 years, and 10% of the capital cost
Misc. maintenance, parts and material	1% of capital cost	
Capital recovery factor	16.275% of capital cost	10% interest rate and 10 years equipment life
Taxes and insurance	2% of capital cost	
Administration and permits	2% of capital cost	
Solvent adjustment credit	\$0.172/liter (\$0.65/gal)[a]	Recovered solvent for sale or reuse
	231/Mg (\$210/ton)	Typical mixed solvent density at 0.742 Kg/liter (6.2 lbs/gal)

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[a] Ref. 15.

TABLE 8-6. ITEMIZED ANNUAL OPERATING COSTS OF VOC CONTROL BY CARBON ADSORPTION FOR ROTOGRAVURE PUBLICATION MODEL PRINTING PLANTS[a]

PLANT SIZE	Small	Small	Small	Large	Large	Large
OVERALL VOC CONTROL EFFICIENCY, %	75	80	85	75	80	85
Carbon adsorption system capacity (solvent laden air flow rate); m^3/hr (ACFM)	90,560 (53,300)	97,800 (57,560)	126,790 (74,620)	163,020 (95,940)	177,510 (104,470)	235,490 (138,590)
Fuel for steam generation ($0.0164/pound recovered solvent)	$ 86,800	$ 92,500	$ 98,200	$173,500	$185,000	$196,500
Electricity ($577/1000 m^3/hr total process exhaust, per year)	42,400	46,600	62,800	84,200	92,600	125,500
Water and water treatment	3,400	3,600	3,900	6,800	7,300	7,700
Labor - Operating (1460 hrs/yr @$12.00/hr) - Maintenance (320 hrs/yr @$13.20/hr) - Engineering supervision	17,500 4,200 5,000	17,500 4,200 5,000	17,500 4,200 10,000	17,500 4,200 5,000	17,500 4,200 5,000	17,500 4,200 10,000
Maintenance parts and materials (1% of installed capital cost)	13,100	13,800	17,900	20,300	22,000	26,800
Carbon replacement and valve seal replacement, including labor (2% of installed capital cost)	26,200	27,600	35,900	40,600	44,000	53,600
Taxes and insurance (2% of installed capital cost)	26,200	27,600	35,900	40,600	44,000	53,600
Administration and permits (2% of installed capital cost)	26,200	27,600	35,900	40,600	44,000	53,600
Total annual operating costs	$251,000	$266,000	$322,200	$433,300	$465,600	$549,000

[a] First quarter 1979 dollars

figures indicated the average was closer to \$0.032/kWhr.[19,23,24,27] This figure is more representative of the volume of consumption and geographical cost differences experienced within the industry. Electrical utilities consumption is estimated at 5470 hours per year (75 percent of scheduled operation). The annual rate of consumption is about 64.9 Gj per 1000 m^3/hr of SLA (30,630 kWh per 1000 CFM of SLA) from the production presses. Hence, the annual electrical cost is \$577 per 1000 m^3/hr (\$980 per 1000 CFM) of production press exhaust. These figures are based on a total electrical power requirement of 5.6 kW/1000 CFM of SLA from the production presses. This power consumption accounts only for the emission control system. Also, the expected water consumption is based only on the emission control system needs.

The calculations of water usage are based on expected make-up for cooling tower losses and boiler losses on an individual plant basis. The cost of water is estimated at \$0.198/m^3 (\$0.75/1000 gal.).

The operating labor cost is estimated at \$17,500/yr and the maintenance labor cost is estimated at \$4,200/yr for all the model plants. The operating labor rate is estimated at \$12.00/hr, which includes fringe benefits. Industry sources indicate the operating labor required for a carbon adsorption unit is about 20 percent of a man's time per shift.[19,23,24,27] The maintenance labor required is about 40 man-days per year[19,23,24,27] at a rate of \$13.20/hr. Periodic engineering supervision is required to insure that the adsorption units are operating efficiently. This cost is estimated at \$5,000 per year.[19,23,24,27] The 85 percent efficient systems have to be maintained at their peak efficiency which requires engineering supervision on a more regular basis. Hence, the cost for these cases is estimated at \$10,000 per year.

The activated carbon in the adsorption units should have a useful life of more than 5 years, as described in Chapter 4. However, to be conservative, costs were included to completely replace the carbon bed. Since the carbon adsorption unit must be partially dismantled to replace the activated carbon, it is also a good time to replace any worn valve seals in the system. The total estimated cost of the carbon, valve seals, and the labor required for this work is estimated at 10 percent of the installed capital cost; distributed out over 5 years, the annual cost is 2 percent.

The annual capital charges are based on a capital recovery factor of 16.275 percent (10 percent interest, 10 year equipment life). The annual capital charges are determined by multiplying the installed capital cost (from Table 8-4) by the capital recovery factor. These charges are calculated for each model plant.

The solvent recovery credit is the dollar-value of the recovered solvent, for a period of one year. The amount of recovered solvent is determined by subtracting the expected emissions from the potential emissions, using Table 6-1 in Chapter 6. This is determined for each model plant. The solvent, as recovered, is suitable for immediate reuse in the presses or may be resold to an ink manufacturer. For this reason, the credit is figured at the full market value of the solvent. The market value of the solvent in early 1979 as established through discussions with several printers and a producer was \$0.172/liter (\$0.65/gal).[15] Therefore, the annual solvent credit is \$231/Mg (\$210/ton) of recovered solvent, assuming 0.742 Kg/liter (6.2 lbs/gal) for typical mixed solvents.

The total annualized costs associated with the operation of carbon adsorption systems in the model printing plants are presented in Table 8-7. The cost effectiveness figures are also presented in Table 8-7. In all cases studied, the annualized costs represent a savings (credit). That is to say, in none of these cases is there a financial loss associated with reclaiming the solvent. These numerical values are intended to illustrate the relative aspects of the total annualized cost and cost effectiveness with respect to the model plant size and overall level of control. A graphical representation of the purchased costs, installed capital costs, and annualized costs is presented in Figure 8-4. The actual model plant cases are illustrated on these curves.

8.2.1.3 Emission Monitoring and Compliance Testing Costs. Emission monitoring is assumed to involve a simple material balance procedure which can be used for compliance testing purposes. This test could involve a month-long period of normal operation in which a detailed solvent material balance is conducted. The official recording of the solvent meter readings (both solvent supply and recovered solvent) and the ink meter readings can

TABLE 8-7. ANNUALIZED COST OF VOC CONTROL BY CARBON ADSORPTION FOR PUBLICATION ROTOGRAVURE MODEL PRINTING PLANTS[a]

PLANT SIZE	Small	Small	Small	Large	Large	Large
OVERALL VOC CONTROL EFFICIENCY, %	75	80	85	75	80	85
Carbon adsorption system capacity (solvent laden air flow rate); m^3/hr (ACFM)	90,560 (53,500)	97,800 (57,560)	126,790 (74,620)	163,020 (95,940)	177,510 (104,470)	235,490 (138,590)
Installed capital cost[b]	$1,310,000	$1,378,000	$1,793,000	$2,032,000	$2,202,000	$2,679,000
Annual operating cost[c]	$ 251,000	$ 266,000	$ 322,200	$ 433,300	$ 465,600	$ 549,000
Annual capital charges[d]	213,200	224,300	291,800	330,700	358,400	436,000
Solvent recovery credit[e]	-554,600	-591,300	-627,800	-1,109,200	-1,182,600	1,256,500
Total annualized cost	$ - 90,400	$ -101,100	$ - 13,800	$ -345,200	$ -358,600	$ -271,500
Cost effectiveness; $/Mg recovered solvent	-37.67	-39.48	-5.07	-71.92	-70.09	-49.82
($/ton recovered solvent)	(-34.18)	(-35.82)	(-4.60)	(-65.26)	(-63.58)	(-45.33)
RETURN ON INVESTMENT (R.O.I.), %	6.9	7.3	0.8	17.0	16.3	10.1

[a] First quarter 1979 dollars.

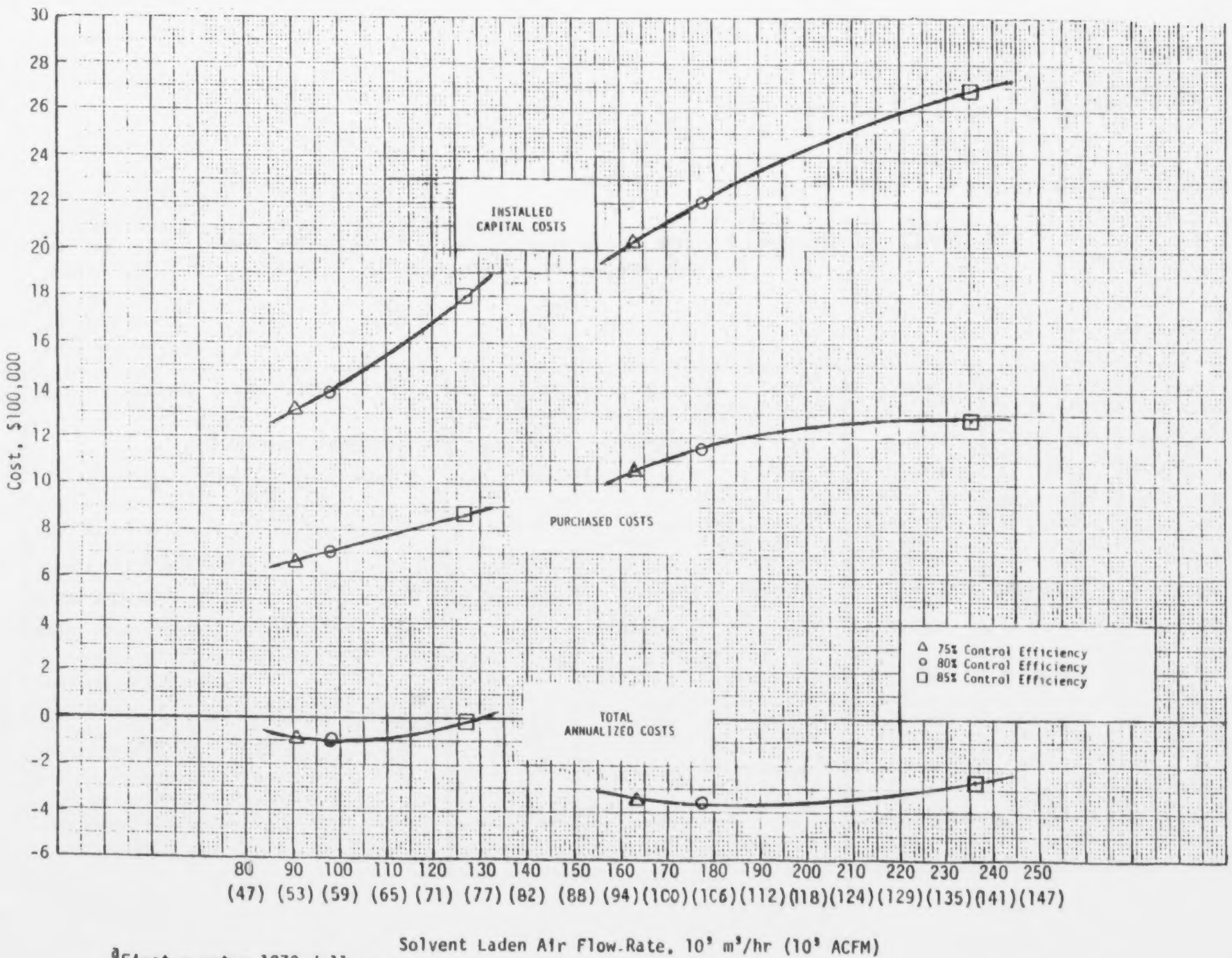
[b] See Table 8-4.

[c] See Table 8-6.

[d] Equal to installed capital cost times the capital recovery factor (Table 8-5).

[e] Equal to Solvent adjustment credit (Table 8-5) times recovered solvent, which equals potential emissions minus expected emissions shown in Table 6-1.

[f] $\text{R.O.I.} = \frac{\text{Total annualized savings}}{\text{Installed capital cost}} \times 100.$



[a] First quarter 1979 dollars

Figure 8-4. Cost of VOC control by carbon adsorption[a] for rotogravure publication model printing plants.

be performed by the operating staff at the plant. An annual allowance of $5,000 to $10,000 has been included in the operating costs presented in Table 8-6. This allowance covers the reporting requirements and additional technical support as required. No additional expenses are anticipated.

Appendix D gives more information on emission measurement and continuous monitoring of controlled rotogravure publication printing facilities.

8.2.1.4 Costs Associated with Increased Water Pollution and Solid Waste Disposal. Carbon adsorption systems have the potential for producing both a solid waste and wastewater. The solid waste results from used fiberglass air filters and spent carbon. The spent carbon is frequently sent back to processors for regeneration and subsequent reuse. Unuseable carbon and used fiberglass air filters can be disposed of commercially for subsequent incineration or landfill. This cost is not a significant expense.

Potential wastewater streams result from (1) contaminated cooling tower blowdown or (2) solvent laden steam condensate. Since the model plants are assumed to reuse the steam condensate as boiler feed water, cooling tower water contamination is eliminated. Boiler and cooling tower water blowdowns are expected to be very small flows, with very low solvent levels. These streams can be disposed of in a municipal sewer system. Consequently, wastewater problems are not considered to be serious, and the costs are not significant.

8.2.2 Modified/Reconstructed Facilities

A complete discussion of the possible changes which result in being classified as a modified or reconstructed facility are presented in Chapter 5. Modifications and reconstructions are not considered a major item of significance in this industry. The cost analysis presented in Section 8.2.1 can be applied to a modified or reconstructed facility, with the following qualifications:

1) An increase in the SLA flow may create a need for more adsorber capacity, which may present a space (land) problem.
2) SLA collection equipment costs may be slightly higher on an older press. This problem results from the generally poor fume containment within older presses.

3) Installation costs for ductwork may be more expensive than for a new plant. This is because the old ductwork may be too small, thus requiring its removal and subsequent replacement with larger ductwork.

8.3 OTHER COST CONSIDERATIONS

The publication rotogravure printing industry is governed by regulations concerning the environment within the plant (i.e. the pressroom, etc.) as well as the outside environment. This study is only concerned with the control of airborne VOC emissions outside the plant (in the outside atmosphere). The responsibility of the working areas within the plant belongs to NIOSH (National Institute for Occupational Safety and Health) and OSHA (Occupational Safety and Health Administration). A discussion of the working area environment is presented in Chapter 7 (7.1.2.2). The costs incurred by the plants, to meet these worker area regulations, are not expected to limit the financial ability of these plants to comply with the proposed New Source Performance Standards (NSPS).

The EPA has issued a guideline document[19], for existing gravure publication facilities, which the states are using to develop SIP regulations. These regulations, which call for a 75 percent VOC reduction, are not expected to financially burden the industry. In fact, the SIP recommendations of 75 percent VOC control will lead to substantial savings of money, solvent, and energy. Consequently, the promulgation of NSPS will not result in any significant economic problems.

8.4 ECONOMIC IMPACT OF REGULATORY ALTERNATIVES

The purpose of this section is to present the potential economic effects of NSPS volatile organic compound recovery requirements on new publication and advertising rotogravure printing facilities. The emphasis of the analysis is to identify possible adverse impacts on industry growth. Other impacts to be examined are those on energy consumption, employment, inflation, foreign trade and balance of payments. The section begins with some relevant supplementary information on the industry, followed by a brief discussion of economic impact analytical methodology. The analysis itself, presented next, is based primarily on the model plants described in

Chapter 6. The section concludes with an examination of industry-wide and national impacts.

8.4.1 Supplementary Industry Profile Data and Economic Impact Assessment Methodology

8.4.1.1 Concentration. In 1972, the four largest firms in the publication gravure industry accounted for 60 percent of the total value of shipments. The eight largest together accounted for 83 percent.[37] A few new firms have entered the industry since 1972, but it remains rather highly concentrated.

8.4.1.2 Integration and Diversification. A completely vertically integrated publication gravure printing concern would be involved in ink and paper production, cylinder preparation, and product sales and distribution. Horizontal integration, strictly speaking, would imply involvement in other printing processes. None of the gravure firms are 100 percent vertically integrated, but a substantial amount of vertical integration is commonplace. Many firms also display significant horizontal integration. In addition, a number of the firms are highly diversified. While little information is available on firms which are privately owned, several examples of publicly-owned corporations are described below.

Macmillan, Inc., owner of Alco-Gravure, considers itself a diversified firm in the "transfer of knowledge" industries. In 1977, printing accounted for 14.2 percent of its total revenues. The remainder was divided among publishing, instruction (Macmillan owns Berlitz and Katharine Gibbs), musical instruments, and "distribution", including book clubs, films, department stores and other retailing. Alco-Gravure specializes in advertising, catalogs, and newspaper supplements.[38]

R. R. Donnelley and Sons Company, on the other hand, is engaged solely in printing, but it is the largest commercial printer in the United States. Donnelley uses all three processes - gravure, offset, and letterpress - and does its own typesetting, platemaking, cylinder preparation, and binding. The company prints books, magazines, catalogs, newspaper inserts, telephone directories, and financial forms and documents.[39]

The Charter Company, a highly diversified firm, owns Dayton Press, Inc. Charter publishes Ladies Home Journal, Red Book, and Sport, and Dayton prints these as well as McCall's, Vogue, House and Garden, Readers

Digest, Newsweek, and Esquire. The Charter Company is also engaged in broadcasting, subscription service, direct marketing, insurance, and oil refining. Printing accounted for less than ten percent of Charter's 1977 gross revenue, and approximately one-third of the printing sales were to other segments of the corporation.[40]

Most of the publicly-owned corporations in the industry fall somewhere within the range characterized by one of the foregoing examples. Some are fairly large, and integrated and diversified primarily within the "communications" field. Others are engaged primarily in printing and publishing with significant vertical and horizontal integration. A few are highly diversified firms in which gravure printing may be a relatively small component. It is difficult to learn much about the private firms, but their names suggest that they are less diversified.

8.4.1.3 Process Economics and Profitability for Model Plants. The publication gravure printing industry carefully guards information on process economics and profitability. Neither the trade associations nor the several individual firms contacted were willing to release any data which could be used in this report. Fortunately, the lack of such material is not critical, for, as presented in Section 8.2, the net cash flow impact of solvent recovery system installation is positive. A rigorous analysis of the absolute effects on profitability was thus neither necessary nor justified, and process economics data were not needed for the examination of comparative impacts on different model plants. Some industry-wide information on profitability is given in the next subsection.

8.4.1.4 Financial Profile of the Industry. Financial information on the publication gravure industry is scarce and difficult to obtain. Statistics are given in government reports for commercial printing (SIC 2751-2-4) and, on a more limited scale, for commercial printing gravure (SIC 2754), but little is presented for gravure publication or advertising printing, (SIC 27541 and 27543). The 1972 Census of Manufacturers reported the following for SIC 27541:[41]

Value added by manufacture	$199,000,000
Cost of materials	$143,600,000
Value of receipts	$343,900,000
Capital expenditures, new	$ 12,000,000
Total employees	10,800
Total payroll	$126,000,000
Total production workers	9,700
Total wages	$109,400,000

The survey conducted in 1976 and 1977 by Gravure Technical Association (GTA) and Graphic Arts Marketing Information Service (GAMIS) contains more extensive statistics for value of gravure-printed publication and advertising products.

1962	$ 561,296,260
1965	$ 785,137,000
1968	$ 972,766,600
1971	$1,210,831,020
1976	$2,129,200,000

GTA/GAMIS used Department of Commerce statistics but also data from printers, equipment manufacturers, publishers groups, trade journals and specialized trade associations.[2] Use of supplementary sources, coupled with revisions to the SIC system which occurred in 1972, probably account for the discrepancy between the Department of Commerce value of receipts and the GTA/GAMIS 1971 product value.

The annual reports of individual publication gravure printing companies which are publicly owned are of little value in further detailing the industry financial profile, because results of publication gravure printing are invariably combined with other printing, with printing and publishing, or with other less closely related operations. Some information could be extracted from them on annual operating profit as a percentage of total sales. For the six firms which reported results in sufficient disaggregation to be useful for this analysis, the average profit for the period from 1973 to 1978 was 8.1 percent of sales.[42]

8.4.1.5 Capital Budgetary Decision Process. In view of the high cost of gravure presses, the long lead times required by press manufacturers, and the present inability of gravure to compete with offset printing on the shorter runs, it is not surprising that expansions of capacity are generally not undertaken on speculation or merely on the basis of projected growth in demand. A review of trade journal announcements of planned expansions gives the impression that a gravure printer often has customers for much of the production of a new press before ordering it. Conversations with trade association staff confirm that expansion to meet existing long-term contracts is commonplace.[43] Discussions with a representative of R. R. Donnelley and Sons Company suggest that it is in fact the usual practice, and that only large firms would undertake speculative expansion. Most gravure plants have a nucleus of one or more long-term customers who utilize a major fraction of press capacity and on whose needs expansion plans are based. Donnelley's Chicago plant, for example, has Sears as its major customer.[43,44] National Enquirer recently signed 10-year contracts with Texas Color Printers and Arcata Graphics (Buffalo) to print its nearly 10 million copy weekly circulation. This triggered an $11 million expansion at Arcata - two new presses with supporting and cylinder engraving equipment.[45] Ten year contracts which specify the initial publishing date and count, and the desired rate of increase in volume are not uncommon. Contracts may be negotiated 12 to 18 months prior to the first printing date.[44]

These practices allow firms to plan orderly expansion and give the customer the opportunity to have specifications met exactly. There are even cases where customers have purchased presses for installation in the plants of their printers. Moreover, the contracts are flexible enough to prevent adverse effects on profits from external factors; prices are permitted to increase with higher materials costs, and there are usually provisions for renegotiation.[44]

8.4.1.6 Supply, Demand, and Price Elasticity. The determinants of supply and demand in the publication gravure industry have been fully discussed in Section 8.1 as a necessary forerunner of the industry growth projections presented there.

There are no published studies of price elasticity for SIC 27541 or 27543, nor were there sufficient price and volume of sales data to permit an elasticity analysis to be conducted in the context of this economic analysis. However, a number of observations suggest that demand is relatively inelastic. First, the industry is successfully convincing growing numbers of customers that its process is the process of choice for high quality work on press runs of 250,000 to 500,000 copies and longer. Many printers agree that offset does not compete well on these long press runs. Second, letterpress printing, with which gravure competes, is a diminishing industry, while gravure continues to grow. Finally, output of gravure-printed publications has climbed steadily, and so have paper, ink, solvent, energy, labor, and therefore production costs and product prices.

8.4.1.7 Economic Impact Assessment Methodology. In this situation, where model plant control cost projections show that solvent recovery has a net positive influence on cash flows, and where no other environmental quality control costs could be identified (Section 8.3), in-depth examination of impacts on profitability using techniques such as discounted cash flow analysis was not warranted. Insofar as profitability was studied, the emphasis, instead, was on the differential impacts which might be felt by plants of different sizes and at different levels of control. Incremental costs or revenues incurred in moving from baseline control to either of the higher levels under consideration were compared. Credit for recovered solvent, a key variable in the control cost equation, was subjected to sensitivity analysis, using present and likely future values for solvent.

In considering whether industry growth might be affected by a proposed NSPS, the capital investment in model plant control equipment was added to that for plant and process equipment with baseline controls. The percentage increase in required capital was examined with respect to capital availability. This portion of the assessment was necessarily quite general, since little data on capital investment for model plants could be obtained.

In order to comply with the requirements of Executive Order 12044, total annualized control costs were calculated and examined to ascertain whether they would exceed $100 million in any calendar year between 1979 and 1985. Total additional costs of production, defined here as total annualized control costs, were compared with projected value of industry output, in the absence of specific data for specific products, to determine whether price increases greater than 5 percent could be expected. Energy consumption by control equipment was compared to the 50×10^{12} BTU per year criterion. Investigation of supply and demand effects on the specified critical materials was not relevant for the publication gravure industry.

8.4.2 Impact on New Facilities

The analysis of potential NSPS impacts on industry growth includes examination of effects on capital availability; cash flow, prices, and profitability; product substitution; foreign trade and import competition; and domestic employment. It is based primarily on the model plants described in Chapter 6.

8.4.2.1 Capital Availability. Information on investment in plant and equipment is not as closely guarded as that on profitability but is still difficult to obtain from firms in this industry. Equipment manufacturers and specialized engineering consultants were better sources for capital costs. Prices for a single, eight-unit, 72-inch publication gravure press ordered from Motter Printing Press Company could vary from $3.1 to $5.4 million, depending on options ordered.[46] Discounts of ten percent are given for additional presses ordered at the same time as the first. An average installed price for a typical press and associated process equiment would be approximately $4.5 million.[47]

Experience in design and construction of publication gravure facilities has shown that a typical installation requires approximately 70,000 square feet of building space for a single press and its supporting equipment, including ink and paper storage and solvent recovery systems, bindery, and similar items. The cost of constructing and equipping such a building, including utilities, solvent recovery and other supporting equipment but excluding the press itself and its associated process machinery, commonly ranges from $70 to $80 per square foot.[48,49] Land acquisition is not included in these estimates, nor has it been considered in this analysis. It is usually a small value in relation to the cost of plant and equipment, and it is highly variable depending on geographic location, topography, and many other characteristics. Moreover, it is not possible to predict the number of cases in which it will be a factor; many plant expansions can take place on land already owned by the company involved.

Table 8-8 has been prepared on the basis of the foregoing average costs. They show the estimated investment in plant and installed equipment

Table 8-8. MODEL PLANT INVESTMENT FOR PLANT AND EQUIPMENT, EXCLUDING VOC CONTROLS

Item	2-Press Model Plant	4-Press Model Plant
8-unit, 72-inch presses @ \$4.5 million, less 10% for each press after first	\$ 8,550,000	\$16,650,000
Building and supporting equipment, 70,000 ft^2 per press, @ \$65/ft^2	\$ 9,100,000	\$18,200,000
Total capital investment excluding VOC controls	\$17,650,000	\$34,850,000

required for the two-press and four-press model plants. Costs associated with solvent recovery have been deliberately excluded by reducing the median per-square foot building cost from \$75 to \$65. The reduction was derived from the two-press installed capital cost for controls with 75 percent recovery efficiency (see Table 8-4) in the following manner:

$$\frac{\$1,310,000}{2} = \$655,000 \text{ for single press recovery system}$$

$$\frac{\$655,000}{70,000\ \text{ft}^2} = \$9.36 \text{ cost of recovery per square foot of plant area, rounded off to } \$10$$

In Table 8-9, capital costs for each model plant at 75, 80, and 85 percent overall solvent recovery are presented. The incremental investment required to increase recovery efficiency from the baseline of 75 percent to 80 or 85 percent is shown along with total capital cost. Table 8-10 shows the fraction of total capital investment allocated to VOC control systems at each level of solvent recovery, as well as the incremental capital investment for higher levels of control expressed as a percentage of total capital investment for a baseline (75% recovery efficiency) plant.

Table 8-10 shows that although VOC control equipment represents a significant fraction of total capital investment at any level of control, the incremental capital cost required for either model plant to attain an 80 percent overall solvent recovery efficiency is very small in comparison to the total investment for a new plant with a 75 percent recovery efficiency system. The additional cost of a 85 percent efficient system, in the vicinity of 2 percent in both cases, is more significant but not so large that it would lead to reduced capital availability which could, in turn, restrict growth in the industry.

Second, at the baseline control level, a firm purchasing a new small model plant would be spending a slightly higher fraction, 1.4 percent, on solvent recovery equipment than would the buyer of a new large model plant. At the 80 percent recovery level, this difference is virtually identical. The gap widens to 2.1 percent for 85 percent recovery. The differences are small enough that a real differential impact on a smaller firm's ability to expand its capacity because of capital limitations is unlikely.

8.4.2.2 Cash Flows. Because the overall effect of solvent recovery is a net cash inflow at the levels being evaluated for NSPS, discounted

Table 8-9. TOTAL AND INCREMENTAL CAPITAL INVESTMENT FOR MODEL PLANTS AT THREE OVERALL RECOVERY EFFICIENCIES

	Plant/Equipment +	VOC Control =	Total
Small Model Plant:			
For 75% recovery	$17,650,000	$1,310,000	$18,960,000
For 80% recovery	17,650,000	1,378,000	19,028,000
For 85% recovery	17,650,000	1,793,000	19,443,000
Incremental cost, 75 to 80%			68,000
Incremental cost 75 to 85%			483,000
Large Model Plant:			
For 75% recovery	$34,850,000	$2,032,000	$36,882,000
For 80% recovery	34,850,000	2,202,000	37,052,000
For 85% recovery	34,850,000	2,679,000	37,529,000
Incremental cost 75 to 80%			170,000
Incremental cost 75 to 85%			647,000

Table 8-10. FRACTION OF CAPITAL INVESTMENT ALLOCATED TO VOC CONTROL AT EACH LEVEL OF RECOVERY

	Total Control Cost As Percentage of Total Capital Costs	Incremental Cost As Percentage of Total Baseline Plant Capital Costs
Small Model Plant:		
75% recovery	6.9%	
80% recovery	7.2%	<1%
85% recovery	9.2%	2.5%
Large Model Plant:		
75% recovery	5.5%	
80% recovery	5.9%	<1%
85% recovery	7.1%	1.8%

cash flow modeling was not considered necessary for the economic impact analysis. Total annualized control costs were scrutinized, however, to identify differences in incremental impact on the two model plant sizes. In addition, the solvent recovery credit term in the control cost equation was subjected to sensitivity analysis because it has a substantial effect on the projected costs.

In Table 8-11, total annualized control costs given in Table 8-7 are summarized and the incremental costs associated with 80 percent and 85 percent recovery are shown. Negative total costs represent net cash inflows. Negative incremental costs represent decreases in net control cost or increases in net cash inflows.

The table shows that net cash inflows are projected from any of the three control levels at either size plant due to reuse, return, or sale of recovered solvent. It also shows that a profit-maximizing operation of either size would logically practice 80 percent recovery, or a slightly higher level, since increased profits should result. In moving to the 85 percent control level, however, the annual operating and capital charges begin to exceed the savings and revenue realized from additional recovered solvent (see Table 8-7), and the incremental values in this table become positive, reflecting a decrease in net cash inflow.

Sensitivity analysis showed that the incremental control costs were highly responsive to small changes in the price of recovered solvent. The price used as the basis of the recovered solvent credit in Table 8-7 was $.17 per liter ($.65/gal), the prevailing market price in early 1979. By July 1, 1979, the price had risen to $.21/l ($.80/gal) and was expected to reach $.24/l ($.90/gal) easily by the year's end.[14] Since many solvent components are used in much larger quantities in gasoline production, it is unlikely that any decreases in price will occur in the next five years.

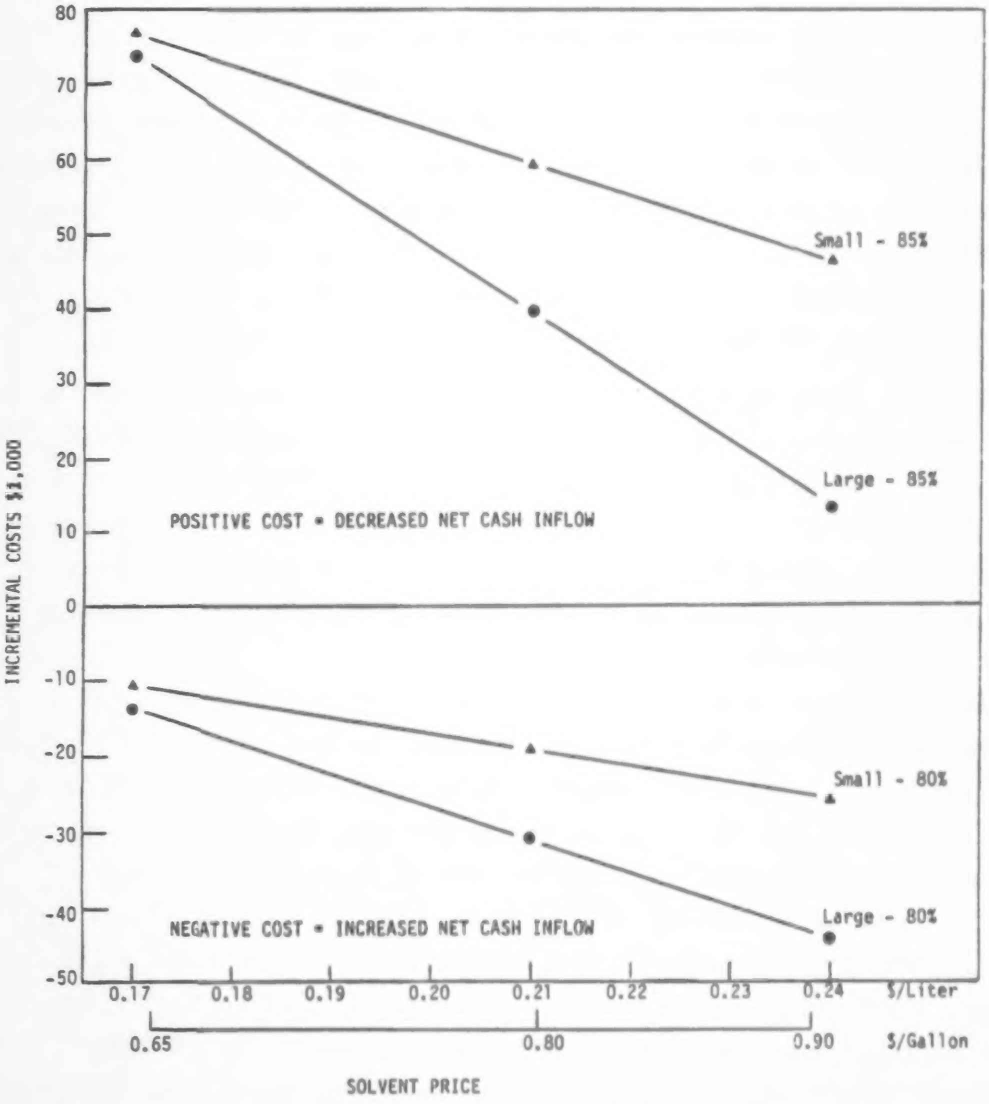
In Figure 8-5, the effects of anticipated increases in solvent price in 1979 on incremental annualized control costs are shown with all other

Table 8-11. TOTAL AND INCREMENTAL ANNUALIZED COST OF VOC CONTROL[a]

	75% Recovery	80% Recovery		85% Recovery	
	Total	Total	Incremental From 75%	Total	Incremental From 75%
Small model plant	$ - 90,400	$ - 101,100	$ - 10,700	$ - 13,800	$ + 76,600
Large model plant	$ - 345,200	$ - 358,600	$ - 13,400	$ - 271,500	$ + 73,700

[a] First quarter 1979 dollars based on a recovered solvent price of $.17/liter ($.65/gallon)--See Table 8-7.

Figure 8-5. INCREMENTAL COST OF VOC CONTROLS ON MODEL PLANTS AT VARIOUS SOLVENT PRICES, ALL OTHER COSTS CONSTANT [a]



[a] First quarter 1979 dollars -- Table 8-7 solvent recovery credit adjusted for increases in solvent cost value.

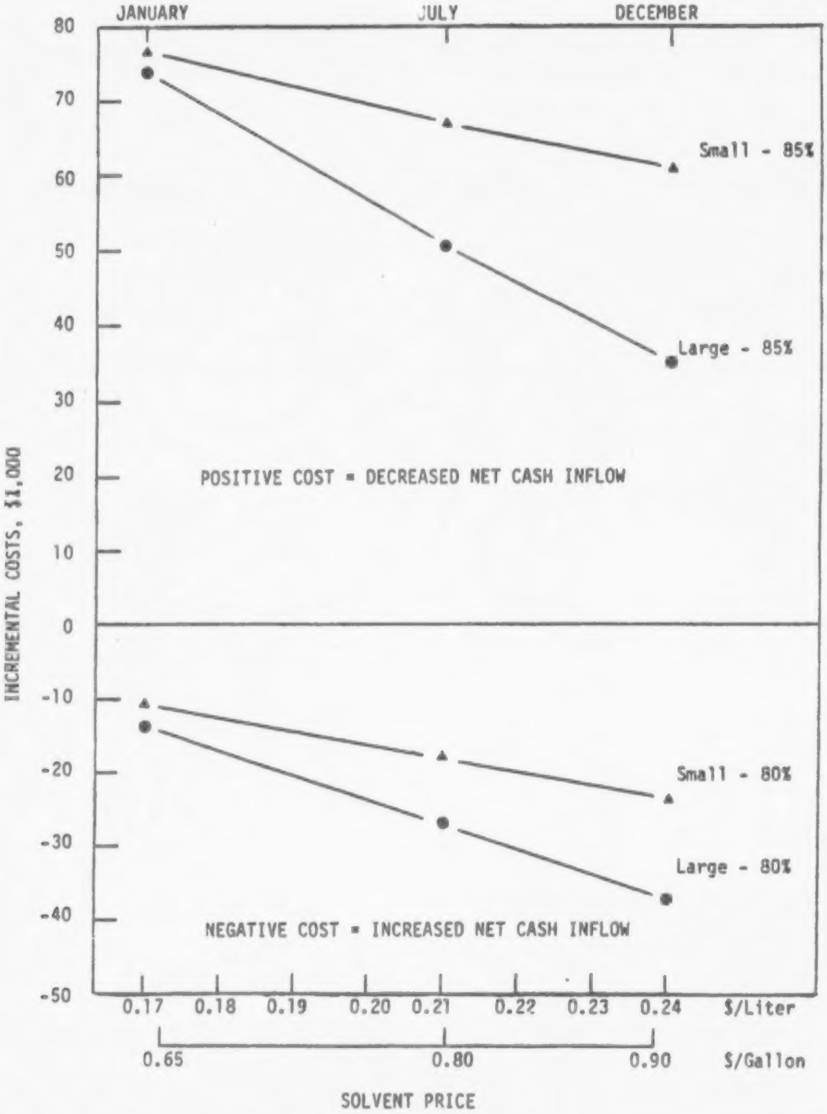
elements of the control costs in Table 8-7 held constant. Figure 8-6 displays similar information with capital and operating control costs increasing by an assumed 5 percent up to the middle of 1979 and about 10 percent to the end of 1979 to compensate for inflation.

Eighty percent recovery has already been shown to be beneficial, from a cash flow standpoint, to either size model plant. The two figures show that with increasing solvent prices, both will enjoy further net increases in cash inflow. At 85 percent, however, both model plants would experience net decreases in cash inflows even with the anticipated near-term solvent cost value increases. The large plant's position improves more rapidly with increasing solvent costs than does the small plant's, so that a gap develops between the two and becomes wider with each increase.

8.4.2.3 Profitability. One conclusion that can be drawn from the cash flow analysis is that profitability will not be adversely affected by imposition of 80 percent recovery requirements on either the two-press or four-press model plant. Consequently, these cases will not be considered further in this subsection, and the profitability analysis will focus instead on the differences in impacts of 85 percent recovery requirements on the two plant sizes.

In the absence of specific information on process economics for a publication rotogravure facility, two assumptions were made for the profitability analysis. The first, based on 1976 industry output and installed capacity, is that the annual gross income produced by a single, eight-unit, 72-inch press at a typical utilization rate of 80 percent of practical capacity is $15.8 million in 1976 dollars. (See Subsection 8.1.2.3 for the basis for this estimate.). This estimate must be inflated to $18.0 million 1979 dollars, on the basis of printing and publishing industry cost and price experience, to permit direct comparison with control costs.[50] The second assumption is that the pre-tax operating income from each press, with baseline (75 percent) solvent recovery, is 8 percent of gross income. (See Subsection 8.4.1.4.) The simplified pro-forma statements in Table 8-12 can then be produced.

Figure 8-6. INCREMENTAL COST OF VOC CONTROLS ON MODEL PLANTS AT VARIOUS SOLVENT PRICES, OTHER COSTS ADJUSTED FOR ASSUMED INFLATION DURING 1979 [a]



[a] Table 8-7 Total Annualized costs adjusted for increases in solvent cost value with 5 percent and 10 percent increases in capital and operating costs through mid to end of 1979, respectively.

Table 8-12. MODEL PLANT ANNUAL OPERATING INCOME AT 75 PERCENT SOLVENT RECOVERY

	Small	Large
Gross Income[a]	$36,000,000	$72,000,000
Less Operating Expenses	33,120,000	66,240,000
Net Operating Income Before Taxes[b]	$ 2,880,000	$ 5,760,000

[a] $18.0 million (1979) income per press

[b] Assumed to be 8.0 percent of gross income

Table 8-13 shows the changes which would occur in those statements at 85 percent recovery, using various solvent prices. This is the "worst case" condition; it assumes that the large plant does not change its product prices and that to remain competitive, the small plant does not increase its prices either, although it experiences slightly higher operating cost because of the increment added for additional solvent recovery. The table shows changes in profit caused by adding the control cost increment to the operating costs and subtracting the total cost from gross income.

This analysis shows that the large plant's rate of operating profit would be consistently higher than the small plant's at 85 recovery. However, the differences are very small, between 0.1 and 0.2 percentage points. Moreover, in neither model does the profit vary by more than 0.2 percentage points from the assumed starting rate of 8.0 percent.

The reason for these small magnitudes of change in profitability is that the absolute values of the incremental control costs are in every case much less than one percent of the total operating expenses. Consequently, while the incremental costs themselves show the small model to be at a slight competitive disadvantage under a standard requiring 85 percent solvent recovery (subsection 8.4.2.2), the effect would be translated into a scarcely noticeable impact on profitability.

8.4.2.4 Prices. The minimal changes in profitability described in the preceding subsection should not result in any significant price changes for gravure products. Prices are likely to rise during the 1980 to 1985 period, but as a result of the continuing paper shortages and increasing energy and ink constituent costs described in Subsection 8.1.2.2.

8.4.2.5 Product Substitution. Because there are no significant NSPS-related projected price increases, implementation of NSPS will not result in product substitution. The present trend of increasing market share in the publication gravure industry would not be affected by implementation of either NSPS under consideration.

8.4.2.6 Small Business Aspects. Officially, a gravure firm qualifies as a small business for loan purposes if it has 500 or fewer employees, including those of the parent corporation. Practically, even the smaller ones of the existing publication gravure firms are not "small" businesses if one

Table 8-13. MODEL PLANT ANNUAL OPERATING INCOME AND PRE-TAX PROFIT AT 85 PERCENT SOLVENT RECOVERY

	Operating Expenses[a]	Net Operating Income[b]	Percentage Profit[c]
Solvent price $.17/l ($.65/gal):			
Small plant	$33,196,600	$2,803,400	7.8
Large plant	66,313,700	5,686,300	7.9
Solvent price $.21/l ($.80/gal):			
Small plant	33,179,400	2,820,600	7.8
Large plant	66,279,100	5,720,900	7.9
Solvent price $.21/l ($.80/gal); all other control costs increased 5%:			
Small plant	33,186,900	2,813,100	7.8
Large plant	66,290,200	5,709,800	7.9
Solvent price $.24/l ($.90/gal):			
Small plant	33,166,500	2,833,500	7.9
Large plant	66,253,000	5,747,000	8.0
Solvent price $.24/l ($.90/gal); all other control costs increased 10%:			
Small plant	33,181,500	2,818,500	7.8
Large plant	66,275,100	5,724,900	8.0

[a] Total expenses for 75 percent VOC control shown in Table 8-12 plus incremental costs for 85 percent VOC control presented in Figures 8-5 or 8-6.

[b] Equal to Gross Income shown in Table 8-12 minus Operating Expenses.

[c] $\text{Profit \%} = \frac{\text{Net Income}}{\text{Gross Income}} \times 100$

considers the size of the necessary capital investment and the extent of integration and diversification. In either case, the analyses in subsections 8.4.2.1 through 8.4.2.3 indicate that within the range of likely new source sizes there would be no major differential impacts related to firm size.

8.4.2.7 Competition From Imports. Foreign trade, relatively minor in this industry at present, would not be affected by the proposed NSPS.

8.4.2.8 Domestic Employment. As industry growth would not be altered by the NSPS under consideration (see Subsection 8.4.2.1), employment would not be adversely affected. New sources will be more heavily automated than existing equipment, however, and this will increasingly limit the number of new jobs made available by each increment of expansion in the industry.

8.4.2.9 Summary of Conclusions for New Facilities. Neither 80 percent nor 85 percent solvent recovery requirements would pose problems of capital availability and thus adverse impacts on industry growth. From a cash flow point of view, it appears to be in the industry's own best interests to recover somewhat more than 80 percent of solvent used voluntarily. Compliance with 85 percent recovery appears less profitable for both size plants at current and projected solvent costs. The differences in impact on the larger and smaller plants at 85 percent would be very small and should not affect competition in the industry. No measurable price impacts are anticipated. Small business would not be adversely affected, nor would foreign trade or domestic employment suffer.

8.4.3 Modified or Reconstructed Facilities

Chapter 5 describes actions which would lead to designation of an existing rotogravure press as a modified or reconstructed facility subject to NSPS. It also presents the reasons for concluding that modification or reconstruction is a highly unlikely event in this industry. These points are discussed more fully in Subsection 8.1.2.4. Because any facilities affected by the proposed NSPS are almost certain to be newly constructed, a separate economic impact assessment has not been conducted for modification or reconstruction.

8.5 POTENTIAL SOCIOECONOMIC AND INFLATIONARY IMPACTS

Socio-Economic Impact Assessment. The purpose of Section 8.5 is to address the tests of macro-economic impact presented in Executive Order 12044 and, more generally, to assess any other significant macro-economic and social impacts that may result from the NSPS.

The economic impact assessment is only concerned with the costs or negative impacts of the NSPS. The NSPS will also result in benefits or positive impacts such as cleaner air and improved health for the population, potential increases in worker productivity, and increased business for the pollution control manufacturing industry. However, these NSPS benefits will not be discussed here.

Executive Order 12044. Executive Order 12044 provides several criteria for a determination of major economic impact. Those criteria are:

1. Additional annual costs of compliance, including capital charges (interest and depreciation), total $100 million (i) within any one of the first five years of implementation (normally in the fifth year for NSPS), or (ii) if applicable, within any calendar year up to the date by which the law requires attainment of the relevant pollution standard.
2. Total additional cost of production of any major industry product or service exceeds 5 percent of the selling price of the product.
3. The administrator requests such an analysis (for example, when there appear to be major impacts on geographical regions or local governments).

8.5.1 Additional Costs of Compliance

As described in Subsection 8.1.2.4, a maximum of 75 new sources are projected to be constructed during the five years this analysis addresses. It is unlikely that more than one four-press expansion or new plant will be opened in any given year; the remainder will be assumed to be two-press facilities, although single press expansions will undoubtedly occur. On an industry basis, then, 75 new gravure presses will be subject to NSPS--five large model plants and 27-1/2 small ones. The incremental annualized costs of VOC control at the 85 percent level versus the 75 percent level was presented in Table 8-11. Thus, the total additional costs of compliance in the fifth year, in early 1979 dollars, for control at the 85 percent level may be projected as follows:

27-1/2 small plants x $76,600 = $2,106,500
5 large plants x $73,700 = + 368,500
Fifth year additional annualized cost = $2,475,000

This is the "worst case " - all other combinations of solvent price and recovery efficiency will yield lower total costs - and it clearly does not nearly reach the $100 million threshold of major economic impact.

8.5.2 Excessive Additional Production Costs

As shown in subsection 8.4.2.3, total additional costs of production will vary by much less than 1 percent. The resulting rates of net profit from operations will be reduced by no more than 0.2 percentage points. Total additional annualized costs will be increased by approximately 0.1 percent of total industry revenues in the worst case. No major economic impact is indicated.

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Appendix A - Evolution of the Backgrourd Information Document

The purpose of this study was to develop a basis for supporting proposed new source performance standards (NSPS) for the publication rotogravure printing industry. Primarily the study involved gathering and analyzing relevant data in such detail that a reasonable performance standard could be developed, proposed, and defended. To accomplish the objectives of this program technical data was acquired on the following aspects of the publication rotogravure printing industry: (1) printing operations and processes; (2) the release and controllability of organic emissions into the atmosphere by this source; and (3) the types and costs of demonstrated emission control technologies. The bulk of this information was retrieved from the following sources:

- open technical literature
- meetings with specific companies, trade associations, and regulatory authorities
- plant visits
- emissions source testing.

Radian Corporation started work on this study in June 1978, following the completion of the EPA screening study. This work was under the direction of the Office of Air Quality Planning and Standards (OAQPS), Emission Standards and Engineering Division (ESED) with Mr. Edwin J. Vincent of the Chemicals and Petroleum Branch (CPB) as the lead engineer. The study was performed under EPA Contract Number 68-02-3058.

In June, 1978, a literature search began with the automated bibliographic and directly type data bases available through Lockhead Retrieval Service's DIALOG and Systems Development Corporation's ORBIT. The data bases search included APTIC, Chemical Abstracts, Engineering Index, NTIS, ENVIROLINE, EIS Plants, Comprehensive Dissertations International, and PAPERCHEM. Most data bases covered the literature from 1970 to the present. The key word "Rotogravure" was used. The information found in the literature was, for the most part, out-of-date or more applicable to specialty and packaging gravure than to publication rotogravure.

The results of the GTA/GAMIS survey were the most valuable outcome of the literature search. This survey was conducted in 1976 by the Gravure Technical Association (GTA) and the Graphic Arts Marketing Information Service (GAMIS) of the Printing Industries of America. From this survey Radian learned enough about the industry to conduct a telephone survey of the industry and its suppliers.

A list of sixteen companies and their subsidiaries (27 plant sites) was obtained from the Gravure Research Institute (GRI) in June, 1978. Key personnel at each of these sites were contacted by phone. It was therefore concluded that the initial list of 27 sites was complete. One of these sites was deactivated in mid-1978, but it was included in the 1977 totals. Table A-1 lists the industry personnel contacted and their titles. These contacts continued from June 1978 to September 1979.

A list of the federal, state and local Air Pollution Control personnel contacted is included as Table A-2. Emissions data was generally available from the state agencies, but there was often confusion about the validity or the interpretation of the figures. Two common problems were bed efficiency given as overall efficiency and data from recent permits given without note of the fact that there might be older presses with less efficient controls, or with no controls, at the same site. Radian sometimes was also given out-of-date information.

A number of industry personnel were willing to discuss their problems and their satisfaction with their emission control systems. Several also gave Radian published brochures detailing the operation and the economics of their systems. Information on specific systems was also gathered during the plant visits listed as Table A-3. Radian relied on vendors and plant visits for details of the most efficient adaptions of fixed bed carbon adsorption, and other available control techniques. The vendors contacted for this study are listed as Table A-4.

The chronological history of the development and evolution of the proposed standards is listed as Table A-5.

In addition to Radian, two other companies also had input to this study. They were JACA Corporation and Monsanto Research Corporation. JACA, under the EPA direction of Mr. Neil Efird of the Economic Analysis Branch (EAB), prepared the economic impact analysis. Monsanto, under the EPA direction of Mr. Frank Clay of the Emission Measurement Branch (EMB), performed all of the emission source testing. Also during Phase II, Mr. William MacDowell of the Standards Development Branch (SDB) helped direct the preparation of the BID and preamble package for presentation at the Working Group, NAPTAC, and Steering Committee meetings.

TABLE A-1. PUBLICATION ROTOGRAVURE INDUSTRY REPRESENTATIVES CONTACTED

ALCO GRAVURE, INC.

Comptroller - North Hollywood, CA.
Bob Gellatly, Eng. Dept. - North Hollywood, CA.
Doug Johnson, Press Room Superintendent - Memphis, TN.
W.A. Milanese, Sr. Vice President of Manufacturing and Technical Services - New York, NY
Marcel Verdooner, Plant Manager - North Hollywood, CA.

ARCATA GRAPHICS

John Dona - Depew, NY
Jerry Uhrland, Manager of Eng. Services - San Jose, CA.

ARCATA PUBLICATIONS GROUP

Frank Beacham, Vice President of Technical services - Stamford, CN.

ART GRAVURE

David Ring, Plant Manager - Cleveland, OH

DAYTON PRESS

Bob Fremgen, Manager of Environmental and Chemical Engineering - Dayton, OH

DENVER POST

Don Ciefer, Head of Rotogravure - Denver, CO.
Robert Zeis, Business Manager - Denver, CO.

DIVERSIFIED PRINTING

Barry Neal, Technical Director - Atglen, PA.

GRAPHIC ARTS TECHNICAL FOUNDATION

Dr. William D. Schaeffer, Research Director - Pittsburgh, PA.

GRAVURE RESEARCH INSTITUTE

Harvey George, Executive Vice President and Research Director - Port Washington, NY

GRAVURE TECHNICAL ASSOCIATION

Warren Daum, Director - New York, NY

Table A-1. (Continued)

GRAVURE WEST

J. Stegeman, Plant Manager - Los Angeles, CA.

KABLE PRINTING CO.

Richard Watson, Manager of Printing - MT. Morris, IL.

MEREDITH CORP.

Bob Cottrell, Vice President & Head of Eng. - Des Moines, IA.
John Downey, Plant Manager - Des Moines, IA.
Gary Johnson, Vice President of Eng. - Des Moines, IA.
George Ruby, Vice President - Des Moines, IA.

MEREDITH/BURDA, INC.

Heinz Gugler, Director of Eng. - Lynchburg, VA.

NEWSPOINT GRAVURE PLANT-NEW YORK NEWS, INC.

Richard Taglieri, Building Maintenance Manager - Long Island City, NY
Gregory Tyszka, Manager of Gravure Presses - Long Island City, NY

PROVIDENCE GRAVURE, INC.

Jim Stefanik, Eng. Maintenance - Providence, RI.
James Trier, Chief Engineer - Providence, RI.

R.R. DONNELLEY AND SONS CO.

Gerald J. Bender, Manager of Process Eng. & Development Dept. - Chicago, IL.
Stephen Blecharczyk, Project Eng. - Chicago, IL.

SPRINGFIELD GRAVURE CORP.

Tony Ringler, Division of Eng. - Springfield, OH.

STANDARD GRAVURE CORP.

Jim Anderson, Vice President & Technical Director - Louisville, KY
B. Bockman, Vice President & General Manager - Louisville, KY
Jack Uhl, Engineer - Louisville, KY

Table A-1. (Continued)

TEXAS COLOR PRINTERS

Peter Gristansky, Salesman & Personnel Director - Dallas, TX.
Oscar Wargnier, Boiler Room Superintendent - Dallas, TX.
Everitt Williams, Eng. Manager - Dallas, TX.

TRIANGLE PUBLICATIONS, INC.

Fred Duffy, Manager of Manufacturing - Philadelphia, PA.
Edward Hastings, Engineer - Philadelphia, PA.

W.F. HALL PRINTING CO. (CHICAGO ROTOPRINT & HALL OF MISS.)

A.J. Aligretti, Vice President of Engineering - Chicago, IL.

WORLD COLOR PRESS

Fred Nasser - Effingham, IL.
John Newsome, Vice President & Director of Research & Eng. - Effingham, IL.

Table A-2. FEDERAL, STATE & LOCAL AIR POLLUTION CONTROL AGENCY PERSONNEL CONTACTED DURING THE SURVEY OF THE PUBLICATION ROTOGRAVURE INDUSTRY

CALIFORNIA

Johnson Lam, State EPA
Teresa Lee, Bay Area EPA
George Rhett, South Coast EPA

COLORADO

Dan Rogers, State EPA

CONNECTICUT

Dave Nash, State EPA

ILLINOIS

Lalit Banker, Regional EPA
Si Levine, Regional EPA
Gary Melvin, State EPA
Dick Pressler, State EPA
Gary Stonewall, Regional EPA

INDIANA

Robert Ondrusek, State EPA

IOWA

Bob Karachiwala, State EPA
Bob Moss, Polk County EPA

KENTUCKY

Richard Eberhard, Jefferson County EPA

MARYLAND

Donald Palmer, State EPA
Russell Summers, State EPA

MINNESOTA

Tom Townsend, State EPA

MISSISSIPPI

Tom Adams, State EPA

Table A-2. (Continued)

NEW YORK

Sidney Marlow, State EPA

NORTH CAROLINA

Charlotte Chamber of Commerce
James McColman, State EPA

OHIO

Charles Kirk, State EPA
Robert Miles, Columbus EPA
Jim Orleman, State EPA
John Paul, Dayton EPA

PENNSYLVANIA

John Hambright, State EPA
Bill Reilly, Philadelphia EPA

RHODE ISLAND

Douglas McVay, State EPA

TENNESSEE

Tom Dale, Shelby County EPA
James Haynes, State EPA

TEXAS

William Chafin, Fortworth TACB
Robert James, Austin TACB
Jessie Macias, Region 8 EPA
Lawrence Pewitt, State EPA
Charles Shevlin, Austin TACB

U.S. EPA

Harold Barkhaw, OAQPS, MDAD, NADB, RTOP, NC

VIRGINIA

C. B. Holloway, Jr., VACB
A. K. Jain, VACB
W.W. Parks, Region 3 EPA

TABLE A-3. PLANT VISITS

Date	Location
July 24, 1978	R.R. Donnelly & Sons, Co. Chicago, IL
August 14, 1978	Standard Gravure Corp. Louisville, KY
August 15, 1978	World Color Press Salem, IL
September 7, 1978	Alco Gravure Corp. California Rotogravure Div. North Hollywood, CA
September 15, 1978	Meredith/Burda, Inc. Lynchburg, VA
December 11-16, 1978	Meredith/Burda, Inc. (Emission Test) Lynchburg, VA
January 3, 1979	Texas Color Printers Dallas, TX
February 20, 1979	World Color Press (Pre-Test Survey) Salem, IL
February 22, 1979	Texas Color Printers (Pre-Test Survey) Dallas, TX
April 9-13, 1979	Texas Color Printers (Emission Test) Dallas, TX
September 27, 1979	Meredith/Burda, Inc. Lynchburg, VA
January 22-24, 1980	Meredith/Burda, Inc. Lynchburg, VA
May 6, 1980	Standard Gravure Corp. Louisville, KY

Table A-4. SUPPLIERS TO THE ROTOGRAVURE PRINTING INDUSTRY CONTACTED

AMERICAN CECA

Michael Worrall, Manager of Solvent Recovery Division - Oak Brook, IL
Bernard Seguy

CALGON CORP.

Frank Bossie, Sales Representative - Pittsburgh, PA

CHARTER OIL

Mr. Emmerton, Marketing Manager - Houston, TX
Al Youens

COMFORT ENGINEERING

Larry McGee - Austin, TX

CRODA INKS CORP.

Severino Tarinas - Niles, IL

CROFTSHAW ENGINEERS (changed to SIMON-CHROFTSHAW, INC. in 1980)

Mitchell Dundee, President - Larchmont, NY (Before 1980)
Robert Wuyts, Executive Vice President - Red Bank, NJ (After 1980)

DuPONT CO.

John Straub - Wilmington, DE

GOTHAM INK

Sam Kantor - New York, NY

HORNER & CO.

Gene Rodriques - San Antonio, TX

INDEPENDENT PETROLEUM

Greg Browne - St. Louis, MO

INMONT CORP.

Frank Iannuzzi - Louisville, KY
Chuck Wright

JOHN ZINK CO.

Cliff Cantrell - Tulsa, OK

MOTTER PRINTING PRESS CO.

George DeWitt, Sales Manager - York, PA
Michael Loeback

Table A-4. (Continued)

REGENERATIVE ENVIRONMENTAL EQUIPMENT CO.

James Mueller, President - Morris Plains, NJ
Rodney Pennington, Project Manager - Morris Plains, NJ

SPECIALTY SOLVENTS CHEMICALS CO.

Denver, CO

SUN CHEMICAL CORPORATION

Jeffrey Boehlert - Carlstadt, NJ

SUTCLIFFE SPEAKMAN & CO.

William Moses, Sales Manager - Bronxville, NY

TOCKHEIM CORP.

Dave Curtis - Fort Wayne, IN

UNION CARBIDE CORP.

Joseph Spiro - Sales Representative - San Diego, CA
Larry Thomas, Purasiv HR Representative - Tarrytown, NY

VARA INTERNATIONAL

Tom Vara, President - Vero Beach, FL

VIC MANUFACTURING CO.

Tom Cannon, Asst. Sales Manager - Minneapolis, MN

YEARGIN CO.

Paul Duff - Charlotte, NC

Table A-5. EVOLUTION OF PROPOSED STANDARDS

Date	Event
6/78	Literature & Telephone surveys begun
6/27/78	APCA Meeting in Houston, Texas
7/13/78	Meeting in NYC with the GRI and GTA
7/24/78	Plant visit to R.R. Donnelly & Sons Company
7/31/78	Section 114 letters submitted
8/14/78	Plant visit to Standard Gravure Corp.
8/15/78	Plant tour of the World Color Press
8/15,16/78	Third Solvent Recovery Commission Meeting of the GRI in Salem, IL
9/7/78	Plant visit to Alco-Gravure, California Rotogravure Division
9/15/78	Plant visit to Meredith/Burda, Inc.
9/26/78	Issued draft of the Test Plan
11/78	Issued draft of the sections of the SSEIS (BID)
12/11-16/78	Emission test at Meredith/Burda, Inc.
1/79	Preliminary model plant and preliminary Section 8.1 data submitted to EAB
1/3/79	Plant visit to Texas Color Printers
2/79	Final test requests submitted to EMB
2/20/79	Pre-test survey at World Color Press
2/22/79	Pre-test survey at Texas Color Printers
3/79	Final model plant parameters defined; Preliminary BID Chapters 3 through 6 distributed for outside comments
4/4/79	Final report issued for December 1978 Emission Test at Meredith/Burda, Inc.
4/6/79	Response from GRI on model plant parameters
4/9-13/79	Emission test at Texas Color Printers
4/4/79	Preliminary control cost data submitted

Table A-5. (Continued)

Date	Event
5/17/79	Regulatory Alternative Recommendation memo issued
6/25/79	Recommendation memo on the form and level of the standard submitted; concurrence memo draft on model plants and regulatory alternatives submitted
7/19/79	Meeting with project team; Basis for Standards defined
7/31/79	Revised Concurrence memo on regulatory alternatives submitted
8/79	Cost and Economic Analysis completed; Chapter 9 and Regulation submitted
9/28/79	Complete Working Group Package submitted
10/19/79	Final report issued for April 1979 Emission Test at Texas Color Printers
11/02/79	Complete NAPCTAC Package submitted
11/15/79	Working Group Meeting
12/13/79	NAPCTAC Meeting
1/3/80	Meeting with project team; NAPCTAC issues and industry's comments evaluation
1/22-24/80	Supplemental vapor sampling/measurements at Meredith/Burda, Inc.
2/14/80	Meeting with project team; Re-evaluation of data base and rationale for level of recommended standard to complete preparation of Steering Committee Package
3/21/80	Final draft of new Reference Method 29 issued by EMB
3/80	Final report issued for January 1980 vapor measurements at Meredith/Burda
4/10/80	Meeting of all industrial surface coating NSPS projects on regulation requirements for continual compliance; new regulation guidelines issued.

Table A-5. (Continued)

Date	Event
4/24/80	Complete Steering Committee Package submitted
5/6/80	Plant visit to Standard Gravure Corp.
6/3/80	Meeting in Durham, N.C. with GRI, GTA, and other industry representatives about comments on the Steering Committee Package
6/6/80	Reports Impact Analysis submitted
7/8/80	Meeting with project team; Evaluation of long-term overall efficiency control data from Meredith/Burda and Standard Gravure; Rationale for level of recommended standard to complete preparation of AA concurrence package
7/30/80	Complete AA concurrence package submitted
10/1/80	Revised proposal package submitted to Assistant Administrators for concurrence
10/80	NSPS proposed in Federal Register

APPENDIX B

INDEX TO ENVIRONMENTAL CONSIDERATIONS

This appendix consists of a reference system which is cross indexed with the October 21, 1974, Federal Register (39 FR 37419) containing EPA guidelines for the preparation of Environmental Impact Statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the Federal Register guidelines.

APPENDIX B

CROSS-INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document (BID)
1. Background and Summary of Regulatory Alternatives	The regulatory alternatives from which standards will be chosen for proposal are summarized in Chapter 1, section 1.1.
Statutory Basis for the Standard	The statutory basis for proposing standards is summarized in Chapter 3, section 2.1.
Facility Affected	A description of the facility to be affected is given in Chapter 3, section 3.1.
Process Affected	A description of the process to be affected is given in Chapter 3, section 3.2.
Availability of Control Technology	Information on the availability of control technology is given in Chapter 4.
Existing Regulations at State or Local Level	A discussion of existing regulations for the industry to be affected by the standards are included in Chapter 3, section 3.3.
2. Environmental, Energy, and Economic Impacts of Regulatory Alternatives	
Health and Welfare Impact	The impact of emission control systems on health and welfare is considered in Chapter 7, section 7.1.

CROSS-INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS (Concluded)

Agency Guidelines for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document (BID)
Air Pollution	The air pollution impact of the regulatory alternatives are considered in Chapter 7, section 7.1.
Water Pollution	The impacts of the regulatory alternatives on water pollution are considered in Chapter 7, section 7.2.
Solid Waste Disposal	The impact of the regulatory alternatives on solid waste disposal are considered in Chapter 7, section 7.3.
Energy	The impacts of the regulatory alternatives on energy use are considered in Chapter 7, section 7.4.
Costs	The cost impact of the emission control systems is considered in Chapter 8, section 8.2.
Economics	Economic impacts of the regulatory alternatives are considered in Chapter 8, section 8.4.

APPENDIX C
EMISSION SOURCE TEST DATA

Sampling programs to obtain volatile organic compound (VOC) emission data were carried out at two well-controlled plants to provide background data for new source performance standards (NSPS). In addition, long-term plant data were obtained from both tested plants and several non-tested plants.

C.1 MEREDITH/BURDA INC. PLANT

The Meredith/Burda Inc. Plant, located at 4201 Murray Place, Lynchburg, Virginia, was tested during the week of December 11-16, 1978. The Meredith/Burda plant operates a total of six rotogravure publication presses (Phases I, II, and III). The two newest presses, press 505 and 506, were the only presses monitored during the course of this test. These two presses, located in a separate pressroom, are controlled by a separate fixed-bed carbon adsorption/solvent recovery system (Phase III). This plant uses pure toluene as the printing solvent. A unique system is utilized in this pressroom to capture fugitive VOC vapor emissions. A cabin-like structure encloses the top one-third of each printing press. Air is drawn from the pressroom and up through each cabin enclosure. Fugitive solvent vapors from around the printing units and from the paper web are captured by this contained air flow. The resultant solvent laden air (SLA) is directed along with the dryer exhausts to the carbon adsorption system.

The emissions from presses 505 and 506 are controlled by a Lurgi "Supersorbon" carbon adsorption system. The system consists of three adsorption vessels containing activated carbon. Two vessels adsorb simultaneously while the third vessel is stripped using countercurrent live-steam injection. The recovered solvent/steam mixture is condensed, cooled, and separated. The dewatered solvent is sent to the recycle solvent storage tank. The water layer (the condensed steam) is sent to a condensate stripper, where it is contacted countercurrently with warm air. This water is reused as boiler feed water. The toluene laden airstream is then recycled back into the adsorber induction system.

Hydrocarbon measurements were made on a semicontinuous basis at both the inlet and outlet of the carbon adsorbers. Grab samples were collected at the inlet and outlet adsorber sites at the ventilation ducts from vapor control enclosures around both press units (505 and 506). The grab samples were analyzed on-site by gas chromatography to identify and determine concentrations of the components in the gas streams. Mixed (diluted) ink samples were obtained from each of the eight feed tanks on each press for determination of the toluene content. The solvent content of the bulk (undiluted) inks was obtained from the ink manufacturer. Samples of both boiler feed water and the water (steam condensate) from the toluene/water decanter (separator) were also collected for toluene content analysis.

The test program consisted of three sampling periods. Each test period was defined as the time required for all of the three carbon adsorbers to complete a single adsorption-desorption cycle. The test periods ranged from about 8½ to 9 hours. Each adsorber remained in the adsorption cycle for 160-180 minutes, followed by a 50 minute steam desorption, conditioning, and cooling cycle. Breakthrough of the solvent vapors occurring on a particular adsorber started the desorption cycle for that adsorber. This was accomplished by an internal hydrocarbon analyzer. An override timer was used to automatically initiate desorption in the event that the hydrocarbon analyzer did not breakthrough.

During the test program, velocity data and liquid samples were collected by Mr. Robert Oppenheimer and Mr. James Totura of the Gravure Research Institute (GRI), located in Port Washington, N.Y., 10050. A test engineer from Lurgi was on-site during the test program in order to monitor the operation of the adsorber system. The sampling and on-site analysis were conducted by a Monsanto Research Corporation team consisting of Messrs. W.R. Feairheller (team leader), W. McCurley, W. Meyer, L. Cox, and C. Clark, and was observed by Mr. Frank Clay of the Emission Measurement Branch of the EPA. Mr. Richard Reich of Radian Corporation was on-site to obtain process design and operating information.

C.2. SUPPLEMENTAL SAMPLING AT MEREDITH/BURDA INC.

The Meredith/Burda Inc. plant was revisited for special sampling and measurements of solvent vapors during January 22-24, 1980. The general purpose of the visit was to acquire more data for evaluation of industry's comments, presented at the December 1979 NAPCTAC meeting. Industry representatives mentioned two possible problems with using the December 1978 Meredith/Burda test results as a basis for establishing proposed standards. First, the fugitive-capture cabin enclosure design may create potential OSHA violations by exposing press operators to excessively high concentration levels of solvent vapors. Secondly, the overall solvent recovery results may have been inflated by solvent vapors drawn into the tested pressroom facilities (Phase III) from other non-tested pressrooms.

The results of measurements inside the cabin enclosures showed toluene vapor concentrations as high as 200 to over 300 ppmv during press shutdowns. These vapor concentration levels agree with the Monsanto report for the December 1978 tests. In comparison, the vapor concentration levels above the upper catwalk around the older presses, without cabin enclosures, were measured at 5090 ppmv during press shutdowns. The higher solvent vapor concentrations above the newest presses, with the cabin enclosure, appears to have two causes: (1) higher ambient pressroom vapor concentrations, and (2) maldistribution of air flow through the enclosures which allows stagnant zones of concentrated solvent vapors in the cabin air. In addition, the results of pressroom measurements showed some infiltration of solvent vapors into the newest (Phase III) pressroom.

The ambient air in both an older, and newest pressrooms were measured for toluene vapor concentration levels. The vapor concentrations in the older pressroom ranged from 40 to 50 ppmv; concentrations in the newest pressroom ranged from about 65 to 200 ppmv. The initial thought was that the air flow through the cabin enclosures was too low, thus allowing fugitive vapors to propagate throughout the newest pressroom.

Supplemental measurements revealed two other possible sources which could contribute solvent vapors to the newest Meredith/Burda pressroom. Fresh outside air and recycle air from the cutting areas are drawn through the heating and air conditioning system, which discharges to the newest pressroom. Measurements indicated that recycling the air from the cutting areas is probably the dominant factor causing elevated solvent vapor concentrations in the pressroom air. In addition, it was determined that solvent laden air infiltrates the newest pressroom from other areas of the plant. Measurements showed that some air containing 60 to 70 ppmv toluene vapors is drawn into the newest pressroom from other pressrooms and plant areas. This infiltration of toluene vapors could have inflated the overall solvent recovery results by about three percent. This estimate is based on the assumption that the infiltrated toluene vapors were generated from other printing facilities.

The sampling and vapor measurements were conducted by the Emission Measurement Branch, ESED, of the EPA. The sampling team consisted of Messrs. Winton Kelly (team leader), Frank Clay, and John Brown. Mr. Edwin Vincent of the Chemical Petroleum Branch, ESED, of the EPA was also present to thelp direct the sampling procedure.

C.3 TEXAS COLOR INC. PLANT

The Texas Color Press Inc. Plant is located at 4800 Spring Valley Road, Dallas, Texas. It was sampled during the week of April 9-13, 1979. The Texas Color Printers plant operates two rotogravure publication presses. These two presses (press 741 and 742) were monitored during the emissions test. The dryer exhaust from press 741 and 742 is combined with the dryer exhaust from the gravure proof press. This SLA exhaust stream is controlled by a carbon adsorption, solvent recovery system. Texas Color Printers uses a mixed petroleum fraction for their gravure solvent. Typical toluene and xylene contents are about 30 percent and 4 percent, respectively. The balance of the solvent (66 percent) is lactol spirits. Two grades of gravure ink (Group 1 and Group 5) are used at this plant.

Fugitive emissions are collected by using floor sweeps in the lower areas of the pressroom. The presses have a floor sweep for each unit, located on the side of the press near the ink tank. The floor sweeps are tied into a separate header for each press. The exhaust from these floor sweeps is not treated by the carbon adsorption system. A separate roof fan for each header discharges the floor sweep exhaust into the atmosphere.

The emission control system used at this plant is a Croftshaw design. The system consists of three horizontal adsorption vessels containing activated carbon. Two vessels adsorb simultaneously for a total SLA capacity of 75,000 CFM. The SLA stream collected from the dryer exhausts is drawn through a header system on the pressroom roof. Two 150 HP fans draw the SLA through roll-fed filters and force the air through the adsorption vessels. The treated air stream is ducted into an exit header and discharged to the atmosphere.

The adsorption cycle, which is regulated by a timer, lasts 3 hours per vessel. The cycles are staggered, thus permitting enough time for regeneration of one bed while the other two are adsorbing. Regeneration is accomplished by countercurrent live steam stripping of the adsorption vessel. The 45 minute regeneration cycle is controlled by a timer. A 15 minute cooling period immediately follows regeneration. The cooling cycle consists of placing the hot, wet, newly regenerated bed on line, to operate along with the other two beds. The inlet SLA, which enters at about 100°F, cools and removes excess moisture from the bed. After the cooling cycle, the newly regenerated bed is taken off line until it is needed. During the regeneration cycle, the stripping steam passes through an adsorber and into the condensers. The two phase condensate is cooled and sent to the decanter. The dewatered solvent flows from the decanter into the underground solvent storage tanks. The steam condensate flows from the decanter into a hot well, where the condensate is recycled as boiler feed water.

Total hydrocarbon and specific compound gas chromatographic analysis data were collected on a semicontinuous basis at both the inlet and outlet of the carbon adsorber system. The solvent vapors from two presses and a proof press are captured by the air handling system. The solvent in the air is removed and recovered by the carbon adsorbers. The air in the room around the presses is ventilated by a separate system which is emitted directly to the atmosphere (uncontrolled). Grab samples of this ventilated air were collected and analyzed by on-site gas chromatography for specific chemical compounds. Samples of diluted ink were obtained from each of the ink feed tanks on the two presses for determination of solvent content. Raw (undiluted) ink samples were also obtained and analyzed. Samples of the water layer (steam condensate) from the solvent/water decanter (separator) were also collected and analyzed for solvent content.

The test program consisted of three sampling periods. Each test period was defined as the time required for all of the three carbon adsorbers to complete an adsorption-desorption cycle. The test periods lasted about 4½ hours during which each adsorber remained in the adsorption cycle for about 180 minutes, followed by a 45 minute desorption (steaming) period and a 10 minute cooling and conditioning period. Two of the three carbon beds were in the adsorption cycle at all times. At the beginning and end of each test period, the solvent supply meter, the decanter solvent meter, and the ink meters readings were recorded.

The sampling and on-site analysis was conducted by a Monsanto Research Corporation team consisting of Messrs. W.R. Feairheller (leader), K. Tackett, W. McDonald, and D. Sterling, and was observed by Mr. Frank Clay of the Emission Measurement Branch of EPA. Mr. Gary Hipple of Pollution Control Science, Inc., Miamisburg, Ohio, collected samples for total gas non-methane organic (TGNMO) analysis during the test program. Pollution Control Science was hired as a subcontractor by Monsanto Research Corporation. Mr. Richard Reich of Radian Corporation was on-site to obtain process deisgn and operation information. The test program was observed by representatives of the Texas Air Control Board (TACB) and the Gravure Research Institute. Mr. Charles Shevlin (TACB-Austin) was present during the entire test period. while Dr. Robert James (TACB-Austin) and Mr. William Chafin (TACB-Fort Worth) were present for a portion of the test. Mr. Robert Oppenheimer and Mr. James Totura (GRI) were present during the entire program and collected samples and data during the test periods.

C.4 SUMMARY OF RESULTS

A summary of the emission control efficiencies for the Meredith/Burda and Texas Color Printers facilities is presented in Table C-1. The overall efficiencies are based on solvent volume material balance data obtained from liquid meter readings acquired from several sources. The Monsanto data are from several short-term, hourly test runs and from one continuous run over several days at each plant. The Radian data for Texas Color represent one continuous run over a slightly longer period than for the Monsanto tests. The GRI data represent independent tests results conducted in parallel with the Monsanto tests but for a slightly longer period. In addition, longer-term monthly plant data were obtained from both tested plants. The calculated apparent overall efficiencies for Meredith/Burda were corrected for temperature variations among the individual liquid meters and for infiltration of solvent vapors into the tested (Phase III) pressroom. The adsorber efficiencies are based on short-term test data obtained by vapor phase analyses and by combinations of liquid meter readings with vapor phase analyses results.

A comparison of the press operations during the Monsanto tests at both plants is shown in Table C-2. The operation of the presses at both plants were practically identical. The frequency of press shutdowns at Texas Color was only slightly higher than at Meredith/Burda. A graphical presentation of the prress shutdown data is shown in Figure C-1. A comparison of the SLA flow streams at both plants is presented in Table C-3. A summary of the longer-term Monsanto test results for both plants is presented in Table C-4.

An explaination of the temperature correction factor required for the Meredith/Burda data is presented in Table C-5. This temperature correction factor is not required for the Texas Color data. At Texas Color, the recovered solvent is at the same temperature as the inks and solvent used at the presses.

The short-term test run data from the Monsanto tests at Meredith/Burda are presented in Table C-6. The capture efficiencies and adsorber efficiencies were determined by combinations of liquid meter readings and vapor phase monitoring results. The overall efficiencies were determined from only liquid meter readings. The overall solvent balances are also useful for determining the amount of product retained solvent. Approximately 3.5 percent of the solvent used was retained in the Meredith/Burda products during the tests, with a capture efficiency of over 96 percent.

A comparison of the amount of solvent recovered at Meredith/Burda as determined by vapor phase measurements and by liquid meter readings is presented in Table C-7. The recovered solvent amounts determined by GC/FID on-line vapor phase measurements range from about 10 to 30 percent lower than by liquid meter readings. The variations in the calculated adsorber efficiencies shown in Tables C-6 and C-7 reflect the differences in the determined recovered solvent quantities.

Adsorber efficiencies determined by the combination of liquid meter readings of recovered solvent with outlet gas phase analyses should be more reliable than by inlet and outlet gas phase analyses. The accurate accounting of solvent vapor into the adsorbers is difficult because of the abrupt changes in solvent vapor concentrations during press shutdowns. The vapor phase analyzers and inlet sampling system may not allow instantaneous instrument response. The inlet vapor concentration varies over a wide range which the analyzer must be calibrated for. The solvent laden air flow through the adsorbers is not constant but fluctuates somewhat during press operations. On the other hand, the outlet vapor concentration is fairly stable except upon breakthrough. Even then, the outlet vapor concentration change is gradual compared to the abrupt inlet changes.

Although vapor phase measurements are useful for determining adsorber bed efficiency, vapor analyses have limited usefulness for accurately assessing overall efficiencies. Continuous vapor phase monitoring is more expensive than liquid phase monitoring. To determine the quantity of recovered solvent by vapor measurements, both air flow and vapor analyses must be continuous and the results of each integrated (by hand or by on-line flow computer) for the entire test time. The test results show that long-term tests are more reliable than short-term tests. Long-term averaging periods are required because of the fluctuations in the printing process and the solvent hold-up in the carbon adsorber beds. Vapor measurements are very difficult to conduct over long periods. In addition, the results of vapor measurements require conversion to equivalent liquid quantities for comparison to the liquid solvent used at the press.

The potential solvent loss from the Meredith/Burda solvent recovery decanter represented about 0.5 percent of the solvent used as shown in Table C-8. However, essentially all of this solvent was recovered by stripping the solvent laden condensate in a special tower. Steam to recovered solvent ratios were also determined to average 3.2 during the tests. The decanter solvent losses were included in a material balance around the adsorbers to determine the adsorber efficiencies, as shown in Table C-9. These efficiencies agree well with those shown in Table C-6.

In addition to the short-term test data, long-term plant data were obtained from the Meredith/Burda plant. Fourteen months of overall solvent recovery performance data are presented in Table C-10. The facilities were reported to be operating normally and at typical conditions except during the four months indicated. The performance results are determined by liquid volume meter readings. The apparent solvent recovery results are adjusted for the temperature correction factor and the factor for infiltration of solvent vapors.

Presented in Table C-11 are theoretical calculations addressing the OSHA violation problem with the Meredith/Burda cabin enclosure design. Air purge times required to decrease the toluene vapor concentration to a safe level inside the enclosure after a press shutdown are shown. The purge time depends on the air flow rate through the enclosure, the initial toluene vapor concentration inside the enclosure at the time of a press shutdown, the desired final toluene vapor concentration after a press shutdown, and the pressroom ambient toluene vapor concentration level (driving force for clearing the enclosure). The results show that the enclosure should be available for safe entry in about one minute after press shutdown for the measured air flow rate and normal pressroom ambient toluene vapor concentrations. An increase in the air flow to the design rate would decrease the required purge times by about 30 percent and would decrease the adsorber efficiency by less than 0.5 percent.

The short-term test run data from the Monsanto tests at Texas Color are presented in Table C-12. The capture efficiencies and adsorber efficiencies were determined by combinations of liquid meter readings and vapor phase monitoring results. The overall efficiencies were determined from only liquid meter readings. The overall solvent balances are also useful for determining the amount of product retained solvent. Approximately 3.3 percent of the solvent used at the press was retained in the Texas Color products during the tests, with a capture efficiency of about 88 percent.

Comparisons of the amount of solvent recovered at Texas Color as determined by vapor phase measurements and by liquid meter readings are presented in Table C-13. Three separate vapor phase analysis methods were employed: GC/FID, TGNMO (EPA Reference Method 25), and FID. The recovered solvent amounts determined by GC/FID and FID methods range from about 15 to 50 percent lower than by liquid meter readings. On the other hand, the recovered solvent amounts determined by the TGNMO method were lower than by liquid meter readings for one run and higher for two of the runs, but the cumulative run totals for the two methods agreed very well. These data show, along with the Meredith/Burda test data, that vapor phase measurements are inconsistent and not reliable for determination of VOC emission control performance in this industry. The variations in the calculated adsorber efficiencies shown in Tables C-12 and C-13 reflect the differences in the determined recovered solvent quantities.

The solvent loss from the Texas Color solvent recovery decanter represented less than 0.1 percent of the solvent used, as shown in Table C-14. Meter readings were not available to determine steam to solvent recovered ratios at this plant. Adsorber efficiencies were determined from material balances, including condensate losses, as shown in Table C-15.

Presented in Table C-16 are the results of a solvent volume material balance conducted by Radian Corporation around the Texas Color facilities. The overall solvent recovery efficiency results are determined from liquid meter readings. The data cover normal operations over several continuous days compared to only two days for the Monsanto tests.

The Texas Color facilities capture only the dryer exhausts. Fugitive solvent vapors are pulled out of the pressroom and discharged directly to the atmosphere through floor sweep vents. Presented in Table C-17 is a comparison of the measured Texas Color adsorber inlet conditions to the estimated adsorber inlet conditions if the floor sweeps were vented to the adsorber.

An estimate of the time-weighted average adsorber efficiency that can be expected for control of VOC emissions in this industry is presented in Table C-18. This estimate is based on the inlet and outlet solvent vapor concentrations measured during the Monsanto tests at Meredith/Burda combined with the press operating data presented in Table C-2 for the Monsanto tests at both tested plants.

As estimate of the increased solvent recovery efficiency that could potentially be achieved by the Texas Color facilities is presented in Table C-19. Estimates are shown for the four data sources presented in Table C-1. The estimates show that the overall solvent recovery efficiency at these facilities could potentially be increased to the 88 to 92 percent range if floor sweeps were vented to the adsorber system.

Analyses of the floor sweeps, presented in Table C-12, showed that an average of 8.2 percent of the solvent is presently vented to the atmosphere. Directing these floorsweeps to the adsorbers could account for increased solvent recovery. Of course, additional adsorber capacity may need to be installed to handle the 31 percent increase in potential air flow (see Table C-17). However, elimination of the "proof press" and "end of header" solvent laden air streams may offset the floor sweep air flow, as shown in Table C-3.

The Texas Color potential increased overall recovery efficiencies include reduced adsorber efficiencies for the more dilute solvent laden air flows. The adsorber efficiencies would decrease about one percent for each case shown in Table C-19. The calculations assume that the differences in the overall recovery efficiencies by the four data sources were caused by variations in product retentions with constant fugitive vapor capture by the floor sweeps. If, on the other hand, the product retentions were constant for all cases, the variations in fugitive captures would yield the same potential overall efficiency as shown for the Monsanto test, since all fugitives would be directed to the adsorber. The Texas Color overall efficiency could be further increased by utilizing gas analyses for concentrating the dryer exhausts and initiating bed regenerations. These features with close capture of fugitive vapors would increase the solvent vapor concentrations and, therefore, would facilitate an average adsorber efficiency of at least 97 percent, as shown in Table C-18.

In addition to the short-term test data, long-term plant data were obtained from the Texas Color plant. Five months of overall solvent recovery performance data are presented in Table C-20. The facilities were reported to be operating normally and at typical conditions during the five month period. The performance results are determined by liquid volume meter readings. No adjustments to the solvent recovery results are required.

C.5 NON-TESTED FACILITIES

Long-term plant data on overall VOC emission control performance were obtained for several non-tested facilities. It is important to recognize that long-term (monthly or four-week periods) performance averaging is more reliable than short-term (hourly, daily, or even weekly) performance averaging for determination of the overall control efficiency level that can be continually achievable. Publication rotogravure printing is characterized by many production upsets (press shutdowns), which affect the performance of the carbon adsorber/solvent recovery system. For this reason, a long-term (one month or four-week period) performance test and monitoring period may be necessary for determination of compliance with the proposed emission standards.

The most significant source of these long-term data is the Standard Gravure, Inc. plant in Louisville, Kentucky. Six publication rotogravure presses are used at this plant. The most important characteristic of this plant is the thorough fugitive solvent vapor capture system. Fugitive solvent vapors are captured from all sections of the plant, including the pressroom, product cutting/folding areas, product storage areas, and the proof press and cylinder preparation areas. This thorough capture system is achieved by ventilating essentially all the air from these plant areas, along with the press dryer exhausts, to the carbon adsorption system. In addition, the more typical, mixed-naphtha based solvents are used at this plant.

Presented in Table C-21 are overall solvent recovery performance plant data for twenty, four-week averaging periods at the Standard Gravure plant. The facilities were reported to be operating normally and at typical conditions, except during the five periods indicated. The performance results are determined by tank truck weighings of purchased inks combined with liquid volume meter readings of the solvent added at the presses and the recovered solvent. No adjustments to the solvent recovery results are required.

There are three reasons why EPA tests were not conducted at the Standard Gravure plant. First, the Standard Gravure emission control system handles much higher air flows to capture fugitive solvent vapors with the dryer exhausts than the tested system at Meredith/Burda or the potential system at the tested Texas Color plant. Secondly, the presses at Standard Gravure were installed in the early 1970's and represent older-type facilities. The older-type presses cannot print as fast and are not as well designed as the modern presses at Meredith/Burda and Texas Color. Thirdly, the liquid meters for the inks used at the presses are not modern meters and are not very accurate. The overall solvent balance using ink tank truck weighings is probably just as accurate as by modern liquid meters, but tank weighings are not the common practice in this industry.

Long-term plant data was also obtained from the World Color Press plant in Salem, Illinois. Routine weekly overall solvent recovery efficiencies reported by this plant are presented in Figure C-2. Only dryer exhausts are treated at this plant; fugitive solvent vapors are not captured. These data show the wide fluctuations in control performance by short-term averaging periods. The long-term performance average at this plant is 80 to 81 percent overall VOC control efficiency.

Long-term plant data were also obtained from several other non-tested plants. These overall control efficiencies are presented in Table C-22. All of these facilities have installed some type of fugitive solvent vapor capture system. The emission control system at the Triangle Publication plant was identical to the system at the Standard Gravure plant, but Triangle's facilities were much older.

TABLE C-1. SUMMARY OF DEMONSTRATED VOC EMISSION CONTROL EFFICIENCIES IN THE PUBLICATION ROTOGRAVURE PRINTING INDUSTRY, PERCENT

Data Sources	Meredith/Burda(Phase III)		Texas Color Printers	
	Overall[a]	Adsorber	Overall	Adsorber
Monsanto Research Corporation tests	89-92[b]	97-99[c]	84[d](92[e])	93-96[f]
Radian Corporation	--	--	83[g](91[e])	--
Gravure Research Institute (GRI) tests[h]	88	99	81	98
Meredith/Burda[i]	84-91	--	--	--
Texas Color Printers	--	--	81[j](89[e])	--

[a] Efficiencies are 5 percent lower than measured apparent efficiencies: 2% for a temperature correction factor (see Table C-5) and 3% for infiltration of solvent vapors.

[b] See Table C-4 and C-6.

[c] See Table C-6, C-7, and C-9.

[d] See Table C-4 and C-12.

[e] Potential efficiency - see Table C-19.

[f] See Table C-12, C-13, C-15.

[g] See Table C-16.

[h] This information appeared in a letter from Harvey F. George (GRI) to Edwin J. Vincent (EPA) dated 9/5/79 - total material balances over 78 hours at each plant.

[i] Monthly plant data - see Table C-10.

[j] Five months of plant data - see Table C-20.

TABLE C-2. COMPARISON OF PRESS OPERATIONS DURING MONSANTO RESEARCH CORP. TESTS AT MEREDITH/BURDA AND TEXAS COLOR[a]

PRESS OPERATION	MEREDITH/BURDA	TEXAS COLOR
Advertising Product-Press:	#505	#1
Press width, inches:	79	94
Web width, inches:	50	62½
Shutdowns/hour (b):	0.27(6.5)	0.60(14.2)
Printing time, %[c]:	86.	78.
Press speed ft/min:	900-1,100	1,700-1,800
Magazine Product-Press:	#506	#2
Press width, inches:	79	94
Web width, inches:	78 3/8	93
Shutdowns/hour(b):	0.58(13.8)	0.37(8.9)
Printing time, %[c]:	64.	72.
Press speed ft/min:	1,500-1,900	900-1,700
Both Presses:		
Shutdowns/hour(b):	0.42(10.1)	0.48(11.5)
Printing time, %[c]	75.	75.
Both up, %[c] (PPM[d]):	60(1,670)	60(1,020)
One up/one down, %[c](PPM[d]):	33(770)	33(500)
Both down, %[c](PPM[d]):	7(300)	7(70)
Total solvent usage, Gal/hr:[e]	143	219
Type of solvent used:	toluene	mixed-naphtha based

[a] Average of three test runs--See Figure C-1.

[b] Equivalent shutdowns per 24 hour period.

[c] Actual press operating time relative to test time.

[d] Adsorber inlet solvent vapor concentrations.

[e] Includes solvent in inks, varnishes, and extenders.

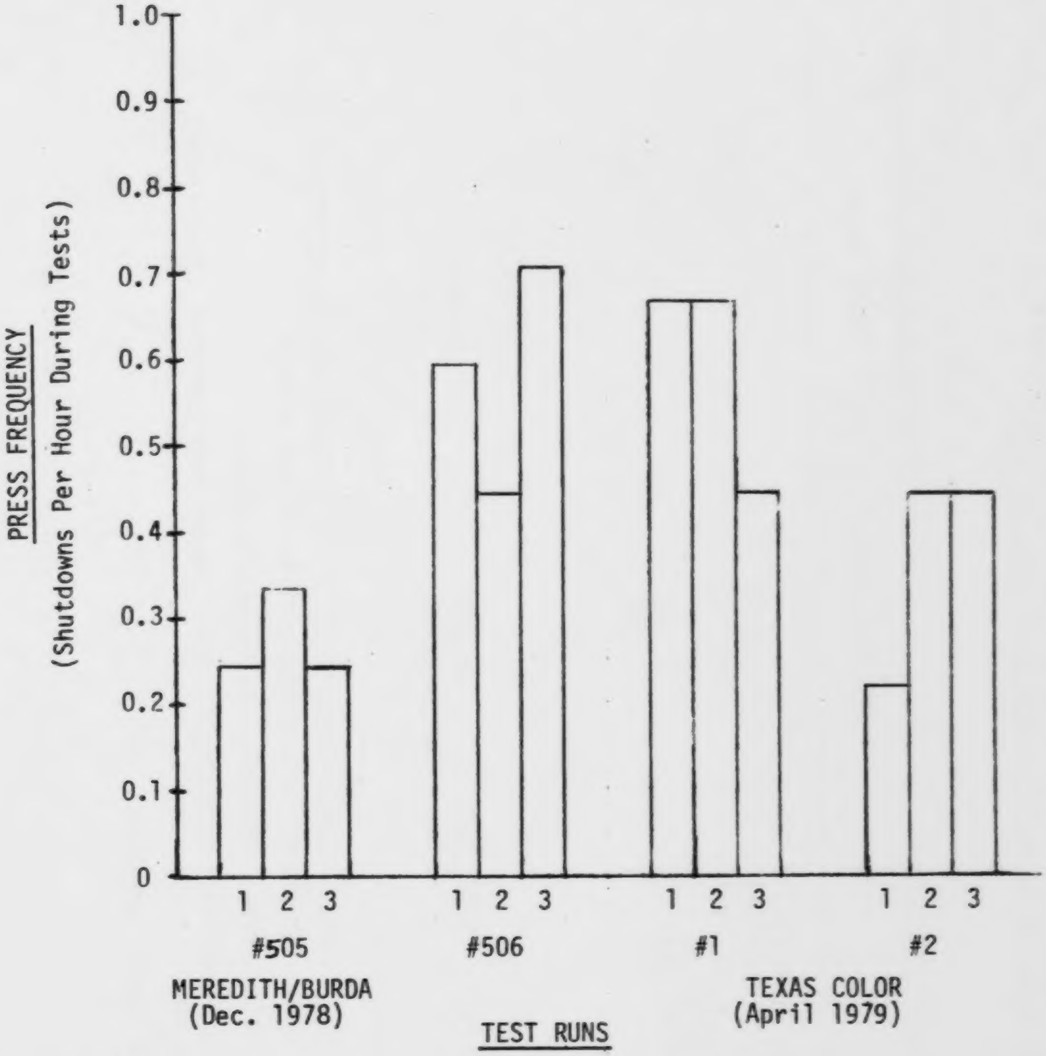

FIGURE C-1. FREQUENCY OF PRESS SHUTDOWNS DURING TESTS
AT MEREDITH/BURDA AND TEXAS COLOR

TABLE C-3. COMPARISON OF SLA* FLOW STREAMS FOR MEREDITH/BURDA AND TEXAS COLOR TESTS BY MONSANTO RESEARCH CORP.

ITEM	SLA* STREAM		MEREDITH/BURDA[a]	TEXAS COLOR	
1	Total adsorber inlet, SCFM (2+3+4+5)				
		cumulative:	48,800	61,200[b]	(80,330)[c]
		per unit:	3,050	-	(3,305)
2	Fugitives capture, SCFM:	Total:	14,400	--	(19,130)
		Per Unit:	900		(960)
3	End of header, SCFM[d]		--	4,300	
4	Proof press, SCFM		--	10,000	
5	Press unit dryer, exhausts, SCFM:	Total:	34,400	46,900	
		Per Unit:	2,150	2,345	
6	Percent fugitives capture, % $(\frac{2}{2+5})$		29.5	--	(29.0)

[a] 2 presses--16 units total; cabin enclosures around top portion of two presses.

[b] 2 presses--20 units total; floor sweeps presently vented to atmosphere.

[c] Numbers in parenthesis would represent conditions if floor sweeps were captured and directed to the carbon adsorption system.

[d] Dilution air to control SLA* header pressure.

*Solvent laden air.

TABLE C-4. SUMMARY OF RESULTS FROM MONSANTO RESEARCH CORP. MATERIAL BALANCE TESTS

Item	Meter Readings	Meredith/Burda[a] (Liters)	Texas Color Printers[b] (Gallons)
1	Total bulk ink and extender input	15,197	3,501
2	Total solvent in bulk ink and extender	9,195	2,248
3	Total solvent added	20,630	3,661
4	Total solvent input (2+3)	29,825	5,909
5	Solvent recovered through decanter	28,165	5,019
6	Apparent average overall recovery efficiency (5/4)	94.4%	84.9%
7	Corrected average overall recovery efficiency	89.4%[c]	NOT APPLICABLE

[a] Total material balance over 51.5 hours, from Dec. 14 through Dec. 16, 1978.

[b] Total material balance over 27 hours, from April 11 through April 12, 1978.

[c] Efficiencies are 5 percent lower than measured apparent efficiencies: 2% for a temperature correction factor (see Table C-5) and 3% for infiltration of solvent vapors.

TABLE C-5. MEREDITH/BURDA RECOVERED TOLUENE SOLVENT VOLUME TEMPERATURE CORRECTION[a]

Liquid Meters	Temperature °C (°F)	Toluene Density[d] g/cc
Raw ink to press[b]	21 (70)	0.866
Extender to press[b]	21 (70)	0.866
Solvent added to press[b]	21 (70)	0.866
Recovered solvent from Decanter[c]	40 (104)	0.849
Correction factor: $(\frac{0.866-0.849}{0.866})$ X 100 = 2.0%		

[a] The calculated apparent efficiencies require a correction factor to compensate for the temperature difference between the recovered solvent and the ink-solvent "input" to the presses. This allowance is necessary because of the volumetric expansion or density change in liquid toluene at various temperatures.

[b] Assumed temperatures--not measured.

[c] Maximum indicated temperature at decanter inlet during regeneration--temperature between regeneration cycles (no flow thru meter) was 30°-32°C (87°-90°F).

[d] Data from Lange's Handbook of Chemistry, McCraw Hill Co., 12th ED., p. 7-367, 10-115, and 10-129; CRC Handbook of Chemistry and Physics, Chemical Rubber Co., 49th ED., P. C-571.

TABLE C-6. SUMMARY OF TEST RUN RESULTS DURING MONSANTO RESEARCH CORP. TESTS AT MEREDITH/BURDA (PHASE III) FACILITIES[a]

Item	Run Test time, hours	1 8.5	2 9.0	3 8.5	Total 26
1	Total solvent to presses, liters	4,186.7	5,253.1	4,605.7	14,045.5
2	Recovered solvent, liters[b]	3,895.5	4,846.1	4,610.9	13,352.5
3	Adsorber outlet loss liters[c]	25.7	79.1	90.6	195.4
4	Condensate-solvent loss, liters[d]	ND	ND	ND	--
5	Product retained, liters[e]	265.5	327.9	--	497.6
6	Percent of total solvent (5/1)	6.3	6.2	--	3.5
7	Apparent overall recovery, % (2/1)	93.0	92.2	100.0	95.1
8	Adjusted overall recovery, %[f]	90.0	89.7	97.3	92.3
9	Capture Efficiency, %[g]	93.7	93.8	--	96.5
10	Adsorber Efficiency, % (7/8)	99.2	98.3	--	98.5

[a] See Figure 4-1, Chapter 4.

[b] Meter readings reduced by 2 percent temperature correction factor--see Table C-5.

[c] GC/FID on-line analyzer/recorder-solvent vapor concentrations were graphically integrated with measured air flow rates to obtain total solvent loss for each run.

[d] ND--less than 3.0 ppm in condensate from stripper--see Table C-8.

[e] [1-(2+3+4)]--Assuming no fugitive vapor losses from pressroom.

[f] Adjusted efficiency accounts for the 3% correction for the infiltration of solvent vapors.

[g] Represents the relative amount of solvent vapors that are captured and directed through carbon adsorbers.

TABLE C-7. COMPARISON OF SOLVENT RECOVERED DATA BY VAPOR PHASE MEASUREMENTS AND METER READINGS AT MEREDITH/BURDA DURING MONSANTO RESEARCH CORP. TESTS

Run	1	2	3	Total
Test time, hours	8.5	9.0	8.5	26
Recovered solvent by meter readings, liters[a]	3,895.5	4,846.1	4,610.9	13,352.5
Recovered solvent by vapor phase measurements, liters[b]	2,640	4,000	4,100	10,740
Adsorber efficiency, %[b]	97.9	98.0	97.2	97.7

[a] Readings reduced by 2 percent for temperature correction factor--see Table C-5.

[b] GC/FID on-line analyzer/recorders for adsorber inlet and outlets. Solvent vapor concentrations were graphically integrated with measured air flow rates to obtain total solvent recovered for each run.

TABLE C-8. SOLVENT LOSS WITH CONDENSATE FROM DECANTER AT MEREDITH/BURDA

Run	1	2	3	TOTAL
Test time, hours	8.5	9.0	8.5	26
Steam/recovered solvent, #/#[a]	3.7	3.0	3.1	3.2
Solvent content from decanter,				
ppm[b]	1,985	720	715	--
liters[c]	28.6	10.4	10.3	49.3
Percent of total solvent[d]	0.7	0.2	0.2	0.4
Solvent content from stripper, ppm[e]	ND	ND	ND	--

[a] Weight per unit weight ratio--27,500 lbs. steam usage by flow meter readings each test run, and recovered solvent @0.866 grams/cc (7.2 lbs/gallon) meter readings shown in Table C-7.

[b] Temperature not measured. Decanter inlet temperature varies--see Table C-5. Literature solubility of toluene in water at 16°C is about 500 ppm.

[c] Calculated assuming condensate flow equal to measured steam flow with solvent density of 0.866 grams/c.c.

[d] Solvent volume loss from decanter divided by total solvent used at the presses (see Table C-6, #1).

[e] Condensate from decanter is stripped of solvent by counter-current contact with hot air--ND is less than 3 ppm.

TABLE C-9. MEREDITH/BURDA CARBON ADSORBER EFFICIENCY TESTS BY MONSANTO RESEARCH CORP.

ITEM	RUN	1	2	3	TOTAL
1	Recovered solvent, liters[a]	3,895.5	4,846.1	4,610.9	13,352.5
2	Decanter solvent loss, liters[b]	28.6	10.4	10.3	49.3
3	Adsorber outlet loss, liters[c]	25.7	79.1	90.6	195.4
4	Total solvent thru adsorber, liters (1+2+3)	3,949.8	4,935.6	4,711.8	13,597.2
5	Adsorber efficiency, % $(\frac{1+2}{4})$[d]	99.3	98.4	98.1	98.6

[a] Meter readings from Table C-7.

[b] See Table C-8.

[c] See Table C-6, #3.

[d] Total solvent recovered by adsorber is equal to metered recovered solvent plus solvent loss from decanter.

TABLE C-10. MONTHLY PLANT OPERATING DATA ON OVERALL EMISSION CONTROL PERFORMANCE SUPPLIED BY MEREDITH/BURDA[a] (SOLVENT QUANTITIES EXPRESSED IN GALLONS)

Item	Solvent Item	April 1979	May 1979	June 1979	July 1979	August 1979	September 1979	October 1979	November 1979	December 1979	January 1980	February 1980	March 1980	April 1980	May 1980
1	Solvent content of bulk ink and extender	21,409	17,445	22,817	26,705	42,891	45,535	48,213	41,037	44,326	36,983	26,113	34,164	30,497	35,691
2	Solvent added to ink	46,888	50,164	54,260	58,487	88,002	100,815	107,652	89,922	108,317	76,455	61,466	80,866	60,545	78,105
3	Total solvent used (1+2)	68,297	67,609	77,077	85,192	130,893	146,350	155,865	130,959	152,643	113,438	87,579	115,030	91,042	113,796
4	Solvent recovered through decanter	63,546	60,510	74,404	66,494	95,862	99,949	66,082	121,340	135,652	102,058	77,534	109,955	85,115	106,916
5	Used Solvent recovered from clean-up	2,200	3,850	-	-	-	-	-	-	-	-	-	-	-	-
6	Total recovered solvent (4+5)	65,746	64,360	74,404	66,494	95,862	99,949	66,082	121,340	135,652	102,058	77,534	109,955	85,115	106,916
7	Apparent average overall recovery efficiency (6/3)	96.3%	95.2%	96.5%	78.1%	73.2%	68.3%	42.4%	92.7%	88.9%	90.0%	88.5%	95.5%	93.5%	94.0%
8	Adjusted average[b] overall recovery efficiency during time period	91.3%	90.2%	91.5%	Emission Control system malfunction				87.7%	83.9%	85.0%	83.5%	90.5%	88.5%	89.0%

[a] This information was supplied by Heinz Gugler (M/B) in two letters: (1) July 6, 1979 to Edwin J. Vincent (EPA), (2) June 19, 1980 to Don R. Goodwin (EPA)

[b] Efficiencies are 5 percent lower than measured apparent efficiencies: 2% for a temperature correction factor (see Table C-5) and 3% for infiltration of solvent vapors.

TABLE C-11. ESTIMATED AIR PURGE TIMES REQUIRED TO DECREASE THE TOLUENE VAPOR CONCENTRATION INSIDE THE MEREDITH/BURDA CABIN ENCLOSURES TO BELOW OSHA STANDARDS LEVEL AT THE TIME OF A PRESS SHUTDOWN, MINUTES[a]

Pressroom concentration, a = ppmv	Air flow rate through cabin enclosure, Q=SCFM	
	7,000 (measured)	10,000 (design)
50	0.9	0.6
100	1.1	0.8
150	1.4	1.0
Adsorber efficiency[b]	98.3 (tested average)	98.1 (calculated)

a. Basis:
1. Cabin is assumed to enclose only the top portion of the eight printing units of a press.
2. Cabin dimensions are assumed to be 51 ft. long by 9 ft. wide by 7 ft. high, for a total volume V = 3,200 cubic feet.
3. OSHA time-weighted average allowable toluene vapor concentration at 200 ppmv.
4. Initial toluene vapor concentration in cabin at press shutdown is Yo = 1,000 ppmv (worst-case).
5. Desired final toluene vapor concentration in cabin after press shutdown is Y = 190 ppmv.
6. Pressroom ambient air toluene vapor concentration ranges from about a = 50 to over 150 ppmv.
7. The measured air flow rate through each cabin enclosure was about Q = 7,000 SCFM; the design rate was Q = 10,000 SCFM.
8. Purge time: $t = \frac{V}{Q} \ln \left(\frac{Yo - a}{Y - a}\right)$

[b] Increasing the air purge to the design flow rate would decrease the adsorber inlet toluene vapor concentration from an average of 1,200 ppmv (see Table C-18) to about 1,080 ppmv.

TABLE C-12. SUMMARY OF TEST RUN RESULTS DURING MONSANTO RESEARCH CORP. TESTS AT TEXAS COLOR PRINTER FACILITIES[a]

ITEM	RUN	1	2	3	TOTAL
1	Total solvent to presses, gallons	900	978	1,078	2,956
2	Recovered solvent, gallons	859	881	764	2,504
3	Adsorber outlet loss, gallons[b]	16.7	70.2	23.2	110.1
4	Condensate-solvent loss, gallons[c]	0.7	0.5	0.7	1.9
5	Floor sweep loss, gallons[b]	61.5	84.7	95.5	241.7
6	Percent of total solvent, % (5/1)	6.8	8.7	8.9	8.2
7	Product retained, gallons[b]	--	--	194.6	98.3
8	Percent of total solvent, % (7/1)	--	--	18.0	3.3
9	Overall recovery, % (2/1)	95.4	90.0	70.9	84.7
10	Capture efficiency, %[e] $\left(\frac{2+3+4}{1}\right)$	97.4	97.3	73.1	88.5
11	Adsorber efficiency, % (9/10)	98.0	92.5	97.0	95.7

[a] See Figure 4-1, Chapter 4.

[b] GC/FID analyses on a semi-continuous basis-integrated with measured air flow rates.

[c] See Table C-14.

[d] [1-(2+3+4+5)]--Assuming no unaccounted fugitive vapor losses from pressroom.

[e] Represents the relative amount of solvent vapors that are captures and directed thru carbon adsorbers.

TABLE C-13. COMPARISON OF RECOVERED SOLVENT DATA BY VAPOR PHASE MEASUREMENTS AND METER READINGS FROM MONSANTO RESEARCH CORP. TESTS AT TEXAS COLOR PRINTERS

Run	1	2	3	TOTAL
Test time, hours	4½	4½	4½	13½
Recovered solvent by meter readings, gallons	859	881	764	2504
Recovered solvent by vapor phase measurements[a]				
GC/FID analysis method, gallons	450	511	675	1636
TGNMO analysis method, gallons[b]	609	953	973	2536
FID analysis method, gallons	536	517	582	1635
Adsorber efficiencies,%[a]				
GC/FID:	96.4	87.9	96.7	93.7
TGNMO:[b]	95.5	96.3	95.4	95.7
FID:	97.1	88.5	96.4	94.0

[a] Recovered solvent was calculated as the difference in total hydrocarbon content of the gas flows in and out of the adsorbers.

[b] Solvent assumed to be 86% carbon with density of 6.6 lbs/gallon.

TABLE C-14. SOLVENT LOSS WITH CONDENSATE FROM DECANTER DETERMINED BY MONSANTO RESEARCH CORP. AT TEXAS COLOR PRINTERS

Run	1	2	3	TOTAL
Test time, hours	4½	4½	4½	13½
Steam/recovered solvent, #/#[a]	4.5	4.5	4.5	4.5
Solvent content from decanter,				
PPM[b]:	171	132	187	--
gallons[c]:	0.7	0.5	0.7	1.9
Percent of total solvent, %[d]	0.07	0.05	0.06	0.06

[a] Weight per unit weight ratio according to plant information--not measured.

[b] Total of Naphtha, Toluene, and Xylene component analyses by GC/FID--temperature not measured. Toluene is largest dissolved component--Naphtha is smallest.

[c] Calculated assuming condensate flow equal to calculated steam flow with solvent density of 0.742 grams/cc

[d] Solvent volume loss from decanter divided by total solvent used at the presses (See Table C-12, #1).

TABLE C-15. TEXAS COLOR CARBON ADSORBER EFFICIENCY DETERMINED FROM TESTS BY MONSANTO RESEARCH CORP.

ITEM	RUN	1	2	3	TOTAL
1	Recovered solvent, gallons[a]	859	881	764	2,504
2	Decanter solvent loss, gallons[b]	0.7	0.5	0.7	1.9
3	Adsorber outlet loss, gallons[c]	16.7	70.2	23.2	110.1
4	Total solvent thru adsorber, gallons (1+2+3)	876.4	951.7	787.9	2,616
5	Adsorber efficiency, % $(\frac{1+2}{4})^d$	98.1	92.6	97.1	95.8

[a] Meter readings from Table C-13.

[b] See Table C-14.

[c] See Table C-12, #3.

[d] Total solvent recovered by adsorber is equal to metered recovered solvent plus solvent loss from decanter.

TABLE C-16. SUMMARY OF TEXAS COLOR PRINTERS TEST RESULTS FROM MATERIAL BALANCES*
BY RADIAN CORPORATION

Item	Meter Readings	Volumes (Gallons)
1	Total bulk ink and extender input	11,508
2	Total solvent in bulk ink and extender	5,382
3	Total solvent added	13,173
4	Total solvent input (2+3)	18,555
5	Solvent recovered through decanter	15,427
6	Average overall recovery efficiency (5/4)	83.1%

*This material balance was conducted in an 82 hour period from 4/9/79 to 4/12/79.

TABLE C-17. ESTIMATED ADSORBER INLET SLA* VAPOR CONCENTRATIONS IF FLOOR SWEEPS VENTED TO TEXAS COLOR ADSORBER

SLA* Stream	Total Hydrocarbons, ppm[a]		Flowrate (SCFM)
	Presses Up	Presses Down	
Adsorber Inlet	1,020	70	61,200
Both Floor Sweeps	400	200	19,130
Potential Adsorber Inlet	870	100	80,330

[a] Average of three test runs by GC/FID analyses for toluene, xylene, and naphtha components.

*Solvent laden air.

TABLE C-18. ESTIMATED ADSORBER EFFICIENCY VARIATIONS FROM MONSANTO RESEARCH CORP. TEST RESULTS

Two-Press Operation	Printing Time,[a] %	Inlet conc.,[b] ppmv	Outlet conc.,[b] ppmv	Adsorber Efficiency %
Both up:	60	1,670	20	98.8
One up/one down:	33	770	20	97.4
Both down:	7	300	20	93.3
Time-weighted average:	--	--	--	97.9

[a] Average of three test runs at both Meredith/Burda and Texas Color--See Table C-2.

[b] Measured at Meredith/Burda.

TABLE C-19. POTENTIAL FOR INCREASED SOLVENT RECOVERY EFFICIENCY AT TEXAS COLOR PRINTERS IF FLOOR SWEEP VENTS WERE DIRECTED TO ADSORBER SYSTEM

DATA SOURCES	Overall Efficiency %	Capture[a] Efficiency %	Potential[b] Capture Efficiency %	Potential Overall Efficiency, %	
				(c)	(d)
MONSANTO (EPA) TESTS	84.7	88.5	96.7	91.7	93.8
RADIAN (EPA) DATA	83.1	86.9	95.1	90.1	92.2
GRI DATA	81.5	85.3	93.5	88.5	90.7
TEXAS COLOR DATA[e]	81.0	84.8	93.0	88.0	90.2

[a] Calculated from material balance around adsorber assuming constant air flow and therefore constant adsorber outlet loss as shown in Table C-12, #3.

[b] Floor sweep solvent content 8.2% of total solvent used as shown in Table C-12, #6; differences in overall recovery efficiency assumed to be caused by variations in product retentions, with constant fugitive vapor capture by floor sweeps.

[c] Calculated from material balance around adsorber for 31% increase in air flow and adsorber outlet losses--Adsorber efficiency would decrease about 1% in each case.

[d] Utilizing gas analyzers for concentrating exhausts and initiating bed regeneration, with close capture of fugitive vapors would facilitate an average adsorber efficiency of 97%, yielding higher overall efficiencies.

[e] This reflects long-term data - see Table C-20.

TABLE C-20. PLANT OPERATING DATA SUPPLIED BY TEXAS COLOR PRINTERS ON OVERALL EMISSION CONTROL PERFORMANCE[a]

(SOLVENT QUANTITIES EXPRESSED IN GALLONS)

Item	Solvent Item	Five month cumulative period during 1979
1	Solvent content of bulk ink and extender	173,160
2	Solvent added (to pressroom)	344,000
3	Total solvent used during period (1+2)	517,160
4	Solvent recovered through decanter	419,000
5	Used solvent recovered from clean-up	-
6	Total recovered solvent (4+5)	419,000
7	Apparent average overall recovery efficiency during time period (6/3)	81%

[a] This information appeared in a letter from Phillip R. Macaskill (TCP) to Richard A. Reich (Radian) dated July 3, 1979.

TABLE C-21. FOUR-WEEK AVERAGED PLANT OPERATING DATA ON OVERALL EMISSION CONTROL PERFORMANCE SUPPLIED BY STANDARD GRAVURE

Four-Week Period/Year	Total Solvent[b] Usage	Steam Usage[a] Ratio	Overall Control[c] Efficiency,%	
10/1978	1.4	5.5	82.1	Emission Control System Malfunction
11	1.5	5.0	80.5	
12	1.5	5.2	81.7	
13	1.2	6.3	85.4	
1/1979	1.1	7.1	81.2	
2	1.3	6.0	85.1	
3	1.5	6.0	86.0	
4	1.4	5.7	85.8	
5	1.2	6.2	90.4	
6	1.4	5.8	87.1	
7	1.2	7.1	86.4	
8	1.4	4.7	85.0	
9	1.3	6.5	87.2	
10	1.4	6.3	87.4	
11	1.4	6.2	88.0	
12	1.5	5.8	89.3	
13	1.3	6.2	89.0	
1/1980	1.0	7.4	85.9	
2	1.1	7.8	86.0	
3	1.3	8.0	88.5	

[a] Pounds of steam per pound of recovery solvent.

[b] Millions of pounds of solvent per period, including solvent in purchased inks.

[c] Total pounds of recovered solvent divided by total pounds of solvent used.

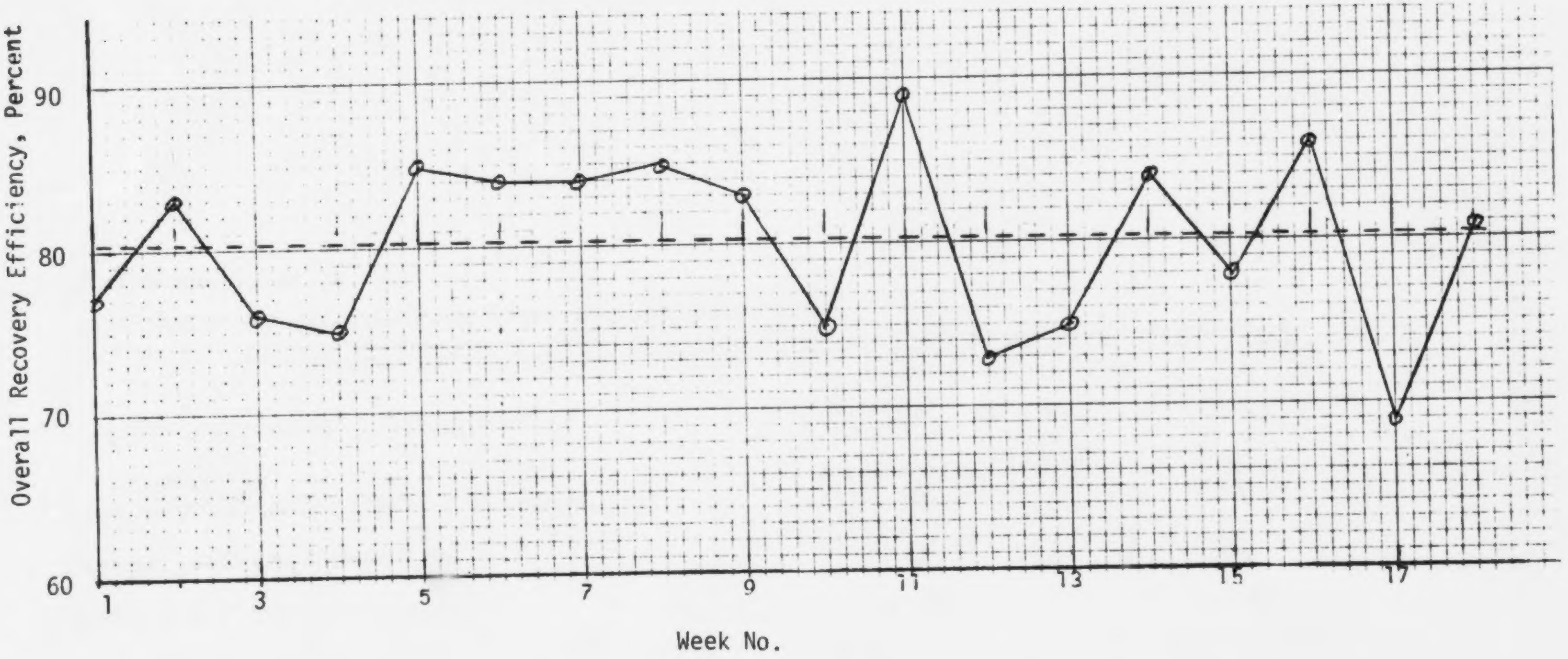

FIGURE C-2. OVERALL VOC EMISSION CONTROL/SOLVENT RECOVERY SYSTEM PERFORMANCE BY WEEKLY AVERAGING PERIODS SUPPLIED BY WORLD COLOR PRESS

TABLE C-22. VOC CONTROL DATA FROM A FEW NON-TESTED PUBLICATION ROTOGRAVURE FACILITIES

DATA SOURCES	FUGITIVES CAPTURE METHOD	OVERALL CONTROL EFFICIENCY, %[a]
Alco-Gravure, Los Angeles, CA	Drop hoses	87-88
Gravure West, Los Angeles, CA	Floor sweeps	90
Older Meredith/Burda (phase I and phase II), Lynchburg, VA	Floor sweeps Without floor sweeps	87 82
Triangle Publication, Philadelphia, PA[b]	All press room air	82-87

[a] Monthly average efficiency estimates reported by plants.

[b] Ceased operations in 1978.

APPENDIX D

EMISSION MEASUREMENT AND CONTINUOUS MONITORING

D.1 EMISSION MEASUREMENT METHODS

During the standard support study for the Publication Rotogravure Printing industry, the EPA conducted tests for volatile organic compounds at two printing facilities. In order to determine solvent recovery efficiencies, ink and solvent samples were taken and analyzed for volatile organic compounds. In addition, stack tests were performed as described in "Measurement of Gaseous Organic Compound Emissions by Gas Chromatography," by W. R. Feairheller, Monsanto Research Corporation under EPA Contract No. 68-02-2818, and, on one test, with the EPA draft Method 25 for determination of Total Gaseous Nonmethane Organic emissions (TGNMO) to evaluate the capture efficiencies of hoods and the control efficiencies of carbon adsorbers.

Of the two facilities tested, both used carbon adsorbers for emission control and solvent recovery. The inlet and outlet of each adsorber system was tested using direct coupling of a gas chromatograph with a flame ionization detector (GC/FID). Sampling was over the entire cycle of the adsorber system. Periodic bag samples were also taken and analyzed for speciation by GC/FID. Ink, solvent, and water samples were taken during the adsorber cycle and analyzed by GC/FID at the contractor's lab after the field test.

At one of the test sites, part of the emissions from the printing process were vented to the atmosphere. These locations were analyzed by collecting bag samples and using a GC/FID for analysis. On this test, TGNMO samples were taken on the adsorber system inlet and outlet and the ducts that vented organic compounds to the atmosphere.

D.2 PERFORMANCE TESTING AND CONTINUOUS MONITORING

During the development of the standard, several methods were considered for demonstrating performance and continuous monitoring of control equipment. Two of these includes the measurement of organic stack emissions or the measurement of the inlet and outlet organic emission rates for determination of control equipment efficiencies. Both of these approaches would have required either the GC/FID or the TGNMO (Method 25) tests performed by EPA during the standard development test program. The third method considered was solvent inventory which measures the solvent used in the printing operation and the solvent recovered by the control device. The first two methods would not account for fugitive emissions which are not captured and removed by the control device where the solvent inventory would measure all solvent loss. Therefore, the recommended method for the demonstration of performance and continuous monitoring for operation and maintenance of control equipment is the measurement of solvent used and the solvent recovered during the printing operation.

To determine the solvent recovery efficiency of a carbon adsorption system used on a Rotogravure printing operation, a solvent inventory system can be used. In such a system, it is necessary to know three things:

(1) the amount of solvent mixed with the raw ink at the ink fountains

(2) the solvent content of the raw ink and varnish as it comes from the supplier

(3) the solvent recovered from the printing operation by the carbon adsorption system

The quantity of solvent used to dilute the raw ink can be obtained from the meter at the solvent storage tank. (This meter will read slightly higher than the sum of the individual solvent meters at the press fountains since a faucet is located in the line prior to each meter and some solvent from each faucet is used for periodic cleaning of press components.)

Quantities of raw ink and varnish used can be obtained from the respective meters located at the fountains and solvent recovered can be read from a meter at the solvent recovery decanter.

Since the raw ink contains a high percent of solvent, the solvent recovered by the adsorption system can be greater than the solvent used from the solvent storage tank. It is necessary, then, to know the quantity of solvent contained in the raw ink and varnish to accurately characterize the system. This can be determined from the ink manufacturer or using a simple evaporative technique. If the same supplier furnishes solvent, ink, and varnish during the period of the solvent inventory, concentration should not change. Furthermore, these components are constantly circulated in their bulk storage tanks, so one analysis of this nature should suffice.

To determine the efficiency of the carbon adsorber system, readings of the solvent used, solvent recovered, and solvent contained in the raw ink and varnish could be collected over a period of 2 to 4 weeks. This time interval would provide accurate data as well as rendering insignificant variations in the process that would otherwise effect the accuracy of similar or other measuring techniques of much shorter duration.